HYDROSIM
User's Guide

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HYDROSIM - User's Guide

The HYDROSIM manual provides all the information needed to use the software. HYDROSIM is essentially a numerical driver deprived of any graphic interface. It functions only in text mode. The main sections of the manual are :

- **Overview of the software**
- **Work procedure**
- **How to manage a simulation ?**
- **How to obtain a hydrodynamic solution?**
- **Appendix**

Chapter 1 Overview of the software

- Uses of the software ;
- Material requirements ;
- User's licence ;
- Launching the software ;
- Language ;
- Physical measurements units ;
- Stopping the software.

Uses of the software

HYDROSIM is a code Finite Elements designed and developed by **{** XE "éléments finis" **}**INRS-Eau, a research center part of Université du Québec, to provide a tool for horizontal two-dimensional simulation of the hydrodynamics of estuaries, rivers and streams. It can be useful to researchers from various fields of interest, but requires some notion of fluvial hydraulics.

The program is based on the solution of the **{** XE "éléments finis" **}**Saint-Venant equations by Finite elements**{** XE "Saint-Venant" **}**, in steady or non steady flow regime, governing the hydrodynamics of streams. HYDROSIM also permits the simulation of drying/wetting conditions on shores and beaches, using a new method developed by scientists at INRS-Eau.

Material requirements

HYDROSIM runs on a personal computer (PC) on the Win32 platforms (Windows 95/98, Windows NT3.51/4.0 etc...)**{** XE "plateforme :Win32" **}** and dynamically manages the memory it requires.**{** XE "mémoire" **}** For optimal performances and good execution speed, it is recommended to run the software in Random Access memory (RAM) rather than on disk memory which considerably reduces execution speed.

The memory needed depends directly on the size of the application to be simulated. The index used to determine the size of a simulation in Megabytes**{** XE "mégabytes" **}** is the total number of degrees of freedom (TNDF**{** XE "NDLT" **}**). For the solution parameters advocated, the memory allocated by HYDROSIM is estimated at bout 6.5×10^{-4} times TNDF**{** XE "NDLT" **}** in Megabytes**{** XE "mégabytes" **}**. As an indicative,

Table 1 presents the memory required for TNDF values ranging from{ XE "mémoire" } { XE "NDLT" }10 000 to 100 000.

Table 1 : Memory required for various TNDF values.										
TNDF (x1000)	10	20	30	40	50	60	70	80	90	100
Memory (Meg)	6.5	13	19.5	26	32.5	39	45.5	52	58.5	65

User's licence

HYDROSIM is a protected software. To use it after the installation, it is necessary to register the software according to the procedure described in the file{ XE "licence :enregistrement" } `hydrosim_enregistrement.txt` available in the same directory as `hydrosim.exe`.

Following registration, one of two (02) types of licence is granted{ XE "licence :type" }:

1 - DEMO : granted for demonstration exercises. Access to certain functionalities of the software is unauthorized. In fact, calculations and printing of results are not possible.

2 - FULL : gives access to all the functionalities of the software. Duration of the licence may be limited or unlimited.

Launching the software

On the Win32 platforms (Windows 95/98, Windows NT3.51/4.0 etc...),{ XE "plateforme :Win32" } the launching of the software is activated in a window in MS-DOS text mode{ XE "exécution :démarrage" } (command prompt), by typing :

```
hydrosim
```

Immediately after being launched, HYDROSIM systematically displays the name of the software. Then, it displays the date, the time and the memory space used. Finally, the information on the software licence are displayed : name of the software{ XE "licence :nom du logiciel" }, access code and type of licence{ XE "licence :code d'accès" }{ XE "licence :type" }.

These information can be displayed either at the prompt or in an output file{ XE "fichier:sortie" }. The software reads the instructions of the fortran number 5 unit and prints the information relative to the progress of the simulation in the fortran number 6. The input/output fortran units 5 and 6 can be redirected

respectively to the command file `fichier.inp` and to the output file as follows:

```
hydrosim < fichier.inp > fichier.out
```

If no input/output files are specified, execution will occur at the prompt. In this case, all the output messages are displayed directly on the screen. Also, immediately after launching, the software is in a scanning mode, which can be deactivated by typing the command**{** XE "mode balayage" **}** STOP.

In the case when the execution is managed by a command file, the scanning mode is automatically deactivated.

The output messages of HYDROSIM are displayed in an output file, if it has previously been specified.

Language

HYDROSIM has a language translation module which translates the internal messages of the software. The language of use is defined in the configuration file**{** XE "langue" **}** `hydrosim.ini`**{** XE "fichier:configuration" **}** using the variable LANGUE. The syntax**{** XE "syntaxe :langue" **}** is as follows :

```
_LANGUE='.xxx'
```

The characters xxx define the language of use (see **Language dictionary**). French is the default language.

Physical measurements units

In HYDROSIM, physical measurements are expressed in the International System (IS) units.

Stopping the software

For an execution without input files**{** XE "fichier:entrée" **}**, a two-step procedure is followed to stop the software. First, you must exit the scanning mode by typing the command STOP followed by *Enter*. The same operation is repeated to stop the software.

Chapter 2 Work procedure

HYDROSIM is a modular software, where each module is dedicated to a specific task. The objective of this chapter on the work procedure is to present all the modules found in HYDROSIM, their function, as well as the prerequisite and dependencies related to their execution. The sections in this chapter address the following items :

- Schematic description
- Structure of the command file
- Structure of file names
- Progress of the simulation

Schematic description

After launching HYDROSIM, the simulation consists in having the different modules work together to reach the overall objective. The different tasks can be achieved using a series of commands.

Schematically, the commands can be classified in three groups :

- input data read commands
- solution commands
- output result printing commands

Structure of the command file

- Definition
- Blocks
- Variables

Definition

The command file comprises instructions and optional commentaries allowing to customize each simulation. The commentaries may be preceded by either one or the other symbol # or !.

All the commentaries preceded by # are automatically printed at the output, which is not the case for those preceded by !.

The instructions are made of a series of commands consisting of Blocks and Variables. The instructions which are systematically found in the command file are the choice of the type of finite element and of the temporal scheme, the definitions of the formulation, data and result files, and calls for blocks to execute specific tasks. Every simulation must be punctuated by the call to the block STOP which ends the execution of HYDROSIM. Thus the command file reads as follows (see **Example of command file**) :

```
# Specimen of command file for HYDROSIM
# Information or identifications relative to
# the simulation

! Choose the type of finite element(see ELTYP).
Instruction
! Choose the type of temporal scheme(see
! STEMP).
Instruction
! Define the formulation (see FORM)
Instruction
! Definition of data and results files.
Instruction
! List of instructions for the acquisition of
! data, the simulation and post-processing.
Instruction
.
.
.
! End of the simulation.
STOP
```

Remark**{** XE "Remarque" **}** : Each instruction must be written on only one line of 1024 characters maximum.

Blocks

Each command is identified by an execution block. Each block has an optional printing unit which returns in output, in part or in totality, the input data and/or information specific to each block. The level of printing of the information is driven by the positive integer m which is equal to 0 by default. The syntax of blocks is**{** XE "niveau :impression" **}** :

```
BLOCK
```

or

```
BLOCK[M]
```

Certain blocks are accompanied by a table of real values :

```
BLOCk(real,real,...,real)
```

or

```
BLOCK[M]( real,real,...,real)
```

The name of each block is a reserved word which must not exceed 4 characters maximum. In HYDROSIM, there are 18 blocks :

- COND
- COOR
- ELEM
- ERR
- FCRT
- FIN
- FORM
- INIT(real,real,...,real)
- PRCO
- PREL

- PRGL(real,real,...,real)
- PRNO
- POST
- RESI
- SOLC
- SOLR
- SOLV(real,real,real)
- STOP

COND

- Function

  Block for reading the boundary CONDitions.

- Variables associated with

  MCND and TASCND

- Prerequisite

  Mandatory to define the variable MCND before calling COND.

  Define the variable TASCND (=0 by default) if the boundary conditions evolve in time, before calling COND.

  Call the blocks COOR, ELEM, PRGL, PRNO, PREL and INIT(real,real,...,real) before calling COND.

COOR

- Function

  Block for reading the mesh COORdinates.

- Variable associated with

  MCOR

- Prerequisite

  Mandatory to define the variable MCOR before calling COOR.

  Call the block FORM before calling COOR.

ELEM

- Function

  Block for reading mesh ELEMents

- Variable associated with

  MELE

- Prerequisite

  Mandatory to define the variable MELE before calling ELEM.

  Call the blocks FORM and COOR before calling ELEM.

ERR

- Function

  Block of calculation of numerical ERRors.

- Variable associated with

  MERR

- Prerequisite

  Define the variable MERR if the printing of numerical errors in a file is desired, before calling ERR.

  Call the blocks FORM, COOR, ELEM, PRGL, PRNO and PREL and INIT(real,real,...,real) before calling ERR.

FCRT

- Function

  Bloc of calculation and printing of the Function CuRrenT.

- Variables associated with

  MFCR for read/write of the function current, MEXE for the progress status of the simulation and ILU, NRDEM, NITER, OMEGA and EPSDL for the solution.

- Prerequisite

  Define the variable MFCR if the printing of the function current in a file is desired as well as ILU, NRDEM, NITER, OMEGA et EPSDL before calling FCRT.

  Call the blocks FORM, COOR, ELEM, PRGL, PRNO, PREL and INIT(real,real,...,real) before calling FCRT.

FIN

- Function

  Bloc of FINal printing of the solution in binary format.

- Variables associated with

  MFIN and FFFIN.

- Prerequisite

  Define the MFIN, if printing of the solution in a file is desired (strongly recommended), and FFFIN before calling FIN.

  Call the blocks FORM, COOR, ELEM, PRGL, PRNO and PREL and INIT(real,real,...,real) before calling FIN.

FORM

- Function

  Block of definition of the FORMulation of the problem. Must imperatively be called at the beginning of each simulation.

- Variables associated with

  ELTYP and STEMP.

- Prerequisite

  Absolutely define the variables ELTYP and STEMP before calling FORM.

  Warning**{** XE "Mise en garde" **}** : After calling FORM, all the data in virtual memory are initialized.

INIT(real,real,...,real)

- Function

  Block of update of the INITial solution of the problem. The syntax of the block is accompanied of an optional table of real containing the initialization parameters associated with the type of finite element (see **Library of finite elements**).

- Variables associated with

  MINI, FFINI and TASINI

- Prerequisite

  Define the variable MINI if the initial solution is stored on file before calling INIT.

  In the case where the initial solution must be read on a file : define the variables FFINI and TASINI, if the initial solution evolves in time, before calling INIT.

  Call the blocks FORM, COOR, ELEM, PRGL, PRNO and PREL before calling INIT.

PRCO

- Function

  Block of calculation of the pointers for a PReCOnditioning of the type matrix ILU.

- Variables associated with

  ILU and DELPRT.

- Prerequisite

  Call the blocks FORM, COOR and ELEM before calling PRCO.

PREL

- Function

  Block for reading the Elementary PRoperties.

- Variables associated with

  MPRE and TASPRE

- Prerequisite

  Define, depending on the type of finite element (see **Library of finite elements**), the variable MPRE before calling PREL.

  Define the variable TASPRE before calling PREL if the elementary properties evolve in time.

  Call the blocks FORM, COOR, ELEM, PRGL and PRNO before calling PREL.

PRGL(real,real,...,real)

- Function

  Block for reading the Global PRoperties.

- Variable associated with

  None

- Prerequisite

  Call the block FORM before calling PRGL.

PRNO

- Function

  Block for reading the NOdal PRoperties.

- Variables associated with

  MPRN and TASPRN

- Prerequisite

  Define, depending on the type of finite element (see **Library of finite elements**), the variable MPRN before calling PRNO.

Define the variable TASPRN if the nodal properties evolve in time, before calling PRNO.

Call the blocks FORM, COOR, ELEM and PRGL before calling PRNO.

POST

- Function

  Block of POST-processing of the results.

- Variable associated with

  MPST

- Prerequisite

  Define the variable MPST before calling POST if printing of the post-processing in a file is desired.

  Call the blocks FORM, COOR, ELEM, PRGL, PRNO, PREL and INIT(real,real,...,real) before calling POST.

RESI

- Function

  Block of calculation of the RESIduals.

- Variable associated with

  MRES

- Prerequisite

  The definition of the variable MRES before calling RESI is mandatory if printing of the residuals in a file is desired.

  Call the blocks FORM, COOR, ELEM, PRGL, PRNO, PREL, INIT(real,real,...,real) and COND before calling RESI.

SOLC

- Function

  Block for reading the Concentrated SOLicitations**{** XE "sollicitations :concentrées" **}**.

- Variables associated with

  MSLC and TASSLC

- Prerequisite

  Mandatory to define the variable MSLC if the concentrated solicitations are stored on file, before calling SOLC.

In the case where the concentrated solicitations are read on file : define the variable TASSLC if the concentrated solicitations evolve in time, before calling SOLC.

Call the blocks FORM, COOR, ELEM, PRGL, PRNO, PREL and INIT(real,real,...,real) before calling SOLC.

SOLR

- Function

  Block for the reading of distRibuted SOLicitations**{** XE "sollicitations :réparties" **}**.

- Variables associated with

  MSLR and TASSLR

- Prerequisite

  Mandatory to define the variable MSLR if the distributed solicitations are stored on file, before calling SOLR.

  In the case where the distributed solicitations are read on file : define the variable TASSLR if the distributed solicitations evolve in time, before calling SOLR.

  Call the blocks FORM, COOR, ELEM, PRGL, PRNO, PREL and INIT(real,real,...,real) before calling SOLR.

SOLV(real,real,real)

- Function

  Block calling the SOLVer. The syntax of the block is accompanied by an optional table of real containing the factors limiting the solution, associated with each type of degree of freedom.

- Variables associated with

  MEXE for the progress status of the simulation. For the others, they depend on the resolution scheme defined by the variable STEMP.

- Prerequisite

  Call the blocks FORM, COOR, ELEM, PRGL, PRNO, PREL, INIT(real,real,...,real), COND, SOLC (optional), SOLR (optional) et PRCO (depending on IMPR) before calling SOLV.

STOP

- Function

  Block to STOP the software.

- Variable associated with

  None

- Prerequisite

  None.

Variables

The variables are always followed by a dynamic field defining them. The syntax of variables**{** XE "syntaxe :variable" **}** is :

```
_VARIABLE=value
```

The dynamic field `value comes in three forms` :

- Type - string of characters between single quotation marks (‘ ‘).
- Type - integer.
- Type - real.

Type - string of characters

The variables of the type string of characters are generally used to define the names of data and results files. Their use may be optional or mandatory. In HYDROSIM, there are 19 variables of the type string of characters :

- ELTYP
- FFFIN
- FFINI
- MCND
- MCOR
- MELE
- MERR
- MEXE
- MFCR
- MFIL
- MFIN

- MINI
- MPRE
- MPRN
- MPST
- MRES
- MSLC
- MSLR
- STEMP

ELTYP

A fundamental variable for any simulation. It defines the TYPe of finite ELement to be used (see **Library of finite elements**).

FFFIN

Variable defining the format (ASCII or binary) of the degrees of freedom file. It may have a ASCII (default) or BIN value.

FFINI

Variable defining the format (ASCII or binary) of the initial solution file. It may have a ASCII (default) or BIN value.

MCND

Variable defining the name or the name extension of the boundary CoNDitions file.

MCOR

Variable defining the name or the name extension of the mesh nodes COoRdinates file.

MELE

Variable defining the name or the name extension of the connectivities of the mesh ELEments file.

MERR

Variable defining the name or the name extension of the results of the numerical ERRors file.

MEXE

Variable defining the name or the name extension of the progress monitoring of the simulation EXEcution file.

MFCR

Variable defining the name or the name extension of the read/write of the Function CuRrent file.

MFIL

Variable defining the generic name or the directory of all the input and output FILes.

MFIN

Variable defining the name or the name extension of the FINal solution printing file.

MINI

Variable defining the name or the name extension of the INITial solution file.

MPRE

Variable defining the name or the name extension of the Elementary Properties file.

MPRN

Variable defining the name or the name extension of the Nodal Properties file.

MPST

Variable defining the name or the name extension of the results of PoSt-Processing file.

MRES

Variable defining the name or the name extension of the results of RESiduals file.

MSLC

Variable defining the name or the name extension of the Concentrated SoLicitations file**{** XE "sollicitations :concentrées" **}**.

MSLR

Variable defining the name or the name extension of the distRibuted SoLicitations file**{** XE "sollicitations :réparties" **}**.

STEMP

A fundamental variable for any simulation. It defines the TEMPoral Scheme to be used. (see **Library of temporal schemes**).

Type - integer

Variables of the type integer are generally used to define the solution parameters. Their use is either optional or mandatory. In HYDROSIM, there are 5 variables of the type integer :

- ILU
- IMPR
- NITER
- NPAS
- NPREC
- NRDEM

ILU

Variable defining the level of filling for a preconditioning of the type matrix**{** XE "niveau :remplissage ILU" **}** ILU. By default, it is equal to 0.

IMPR

Variable defining the type PReconditioning Matrix :

_IMPR=0 for indented matrix

_IMPR=1 for diagonal mass matrix

_IMPR=2 for diagonal tangent matrix

_IMPR=3 for ILU matrix

By default, it is equal to 1.

NITER

Variable defining the Number of ITERations. By default, it is equal to 25.

NPAS

Variable defining the Number of steps for the division of time t in increment Δt in the case of a transient or non stationary simulation**{** XE "transitoire" **}**. By default, it is equal to 1.

NPREC

Variable defining the Number of PREConditioning. By default, it is equal to 1.

NRDEM

Variable defining the Number of Restarts. By default, it is equal to 25.

Type - real

Variables of the type « real » are used to define the parameters of the solution method and the data in a non stationary context. Their use is either optional or mandatory. In HYDROSIM, there re 12 variables of the type « real » :

- ALFA
- DELPRT
- DPAS
- EPSDL
- OMEGA
- TASCND
- TASINI
- TASPRE
- TASPRN
- TASSLC
- TASSLR

- TINI

ALFA

Variable defining the coefficient α (ALFA) of the temporal scheme **EULER**. It can take values between 0 and 1 inclusive. By default, it is equal to 1.

DELPRT

Variable defining the coefficient Δ (DELta) of disruption of the ILU preconditioning matrix. By default, it is equal to 10^{-8}.

DPAS

Variable defining the time step**{** XE "pas de temps" **}** Δt (Delta t) for the discretization of the time. By default, it is equal to 10^{+12}.

EPSDL

Variable defining the precision ε (EPSilon) of the Degrees of freedom. By default, it is equal to 10^{-06}.

OMEGA

Variable defining the factor ω (OMEGA) of relaxation of the degrees of freedom. By default, it is equal to 1.

TASCND

Variable defining the Time ASsociated with the initial reading of the non stationary boundary CoNDitions (see **Processing of transient data**).

TASINI

Variable defining the Time ASsociated with the initial reading of the non stationary INItial solution (see **Processing of transient data**).

TASPRE

Variable defining the Time ASsociated with the initial reading of the non stationary Elementary PRoperties (see **Processing of transient data**).

TASPRN

Variable defining the Time ASsociated with the initial reading of the non stationary Nodal PRoperties (see **Processing of transient data**).

TASSLC

Variable defining the Time ASsociated with the initial reading of the non stationary Concentrated SoLicitations (see **Processing of transient data**).

TASSLR

Variable defining the Time ASsociated with the initial reading of the non stationary distRibuted SoLicitations**{** XE "sollicitations :réparties" **}** (see **Processing of transient data**).

TINI

Variable defining the INItial Time of the simulation.

Structure of file names

The names of the HYDROSIM data and results files are systematically defined by the concatenation of the values of two Variables of the Type - string of characters. In the order, the first common to all files is MFIL and the second is associated with the appropriate block (see Blocks).

Example :

The name of the file associated with block XXX accepting MXXX as variable of the type string of characters, is determined by one or the other of the two following procedures :

```
_MFIL='name1'
_MXXX='name2'
```

or

```
_MFIL=''
_MXXX='name1name2'
```

In both cases, the file name resulting from the association of, in the order, MFIL and MXXX is `name1name2`.

Remark**{** XE "Remarque" **}** : The maximum length of file names cannot exceed 217 characters.

Progress of the simulation

- Definition
- Work load
- End message

Definition

The progress of the simulation is accessible on the simulation monitoring file defined by the variable MEXE (see Structure of file names).

Typically, when a simulation is running, there is only one line of message containing an integer comprised between 1 and 100 in the simulation monitoring file. It expresses, in percentage (%) of the Work load, the state of progress of the problem solving procedure.**{** XE "exécution :avancement" **}**

Work load

The work load is an integer equal to the maximum number of iterations possible**{** XE "exécution :volume" **}**. It is automatically calculated during the scanning mode. It is then displayed at the prompt or in the output file (see **Launching the software**) when the scanning mode is exited.

End message

At the end of the HYDROSIM simulation, the following message appears systematically in the simulation monitoring file**{** XE "fichier:suivi de la simulation" **}** :

```
100
END
```

In the output file or at the prompt, the date and time of the end of the simulation are displayed, as well as the total duration. The memory space used is also given.

Remark**{** XE "Remarque" **}** : The duration of the same simulation may vary if the work conditions are modified.

Chapter 3 How to manage a simulation ?

The objective of this chapter is to present the procedure to build a command file**{** XE "fichier:commandes" **}** (see **Structure of the command file**) from the **Variables** and **Blocks**, to manage a simulation. At each step, the variable to define and the block to call are indicated. To make sure that the rules of dependencies between blocks and variables are respected (see **Block dependencies**), it is recommended to follow the procedure below :

- Create a new simulation
- Define the discretization of the problem
- Read the data
- Solve the problem
- Print the results

Create a new simulation

When creating a new simulation, it is recommended (although optional) to insert in the command file, text (a maximum of 1024 per line) to identify the physical process to be simulated. It consists mainly in indicating the origin of the terrain data, the choice of boundary conditions, of solicitations and of initial conditions. The text could also indicate at which stage the simulation corresponds : initialization, calibration**{** XE "calibration" **}**, prediction...

As a general rule, the more information, the better. This could be particularly useful during the analysis phase. For the information to appear in the output file, make sure that each line of text is preceded by #.

Define the discretization of the problem

Define the variables **ELTYP** (see **Library of finite elements**) and **STEMP** (see **Library of temporal schemes**). Call the block **FORM**.

Example :

To discretize a horizontal 2D fluvial hydraulics problem with prediction of the drying/wetting banks, in a stationary context, the associated command is :

```
_ELTYP='SVCRNM'
```

```
_STEMP='STATIQ'
FORM[0]
```

or, ia transient context :

```
_ELTYP='SVCRNM'
_STEMP='EULER'
FORM[0]
```

Read the data

In general, the data are stored in ASCII files. The reading operation of each type of data consists in defining the name of the data file with the appropriate **{** XE "fichier:données" **}**variables (see **Structure of file names**), defining the associated time and time step in the case of a simulation in time**{** XE "pas de temps" **}**, and activating the appropriate block to proceed with the reading. To integrate the data into HYDROSIM, follow this procedure :

- Read the coordinates
- Read the connectivities
- Read the global properties
- Read the nodal properties
- Read the elementary properties
- Read the initial solution
- Read the boundary conditions
- Read the concentrated solicitations
- Read the distributed solicitations

Read the coordinates

The coordinates are stored in an ASCII file (see **Coordinates file**). Define the **MFIL** and **MCOR**. Call the block **COOR**.

Example :

The element coordinates are in the file test.cor ; the command is :

```
_MFIL='test'
_MCOR='.cor'
COOR[0]
```

Read the connectivities

The connectivities are stored in an ASCII file (see **Connectivit**). Define the variables **MFIL** and **MELE**. Call the block **ELEM**.

Example :

The element connectivities are in the file test.ele ; the command is :

```
_MFIL='test'
_MELE='.ele'
ELEM[0]
```

Read the global properties

The global properties are integrated from the commands file. Call the block **PRGL** and fill the global properties table which follows.

Example :

To integrate the global properties, 5 items in this example, the command is :

```
PRGL[0](9.81,47,1.e-06,1.,1.e+03)
```

Read the nodal properties

The nodal properties are stored in an ASCII file (see **Nodal properties file**). Define only the variables **MFIL** and **MPRN** to assign the file name in the stationary context. In the transient context, add **TASPRN{** XE "transitoire" **}**. Call the block **PRNO**.

Example :

The stationary nodal properties are in the file test.prn ; the command is :

```
_MFIL='test'
_MPRN='.prn'
PRNO[0]
```

In the transient context, the time has to be specified if the nodal properties vary with time, for example load the properties associated with**{** XE "transitoire" **}** t=24h00 :

```
_MFIL='test'
```

```
_MPRN='.prn'
_TASPRN=86400.
PRNO[0]
```

Read the elementary properties

The elementary properties are stored in an ASCII file (see **Elementary properties file**). Define only the variables **MFIL** and **MPRE** to assign the file name in the stationary context. In the transient context, add **TASPRE{** XE "transitoire" **}**. Call the block **PREL**.

Example :

The stationary elementary properties are in the file `test.pre` ; the command is :

```
_MFIL='test'
_MPRE='.pre'
PREL[0]
```

In the transient context, the time has to be specified if the elementary properties vary with time, for example load the properties associated with**{** XE "transitoire" **}** t=12h00 :

```
_MFIL='test'
_MPRE='.pre'
_TASPRE=43200.
PREL[0]
```

Read the initial solution

Two cases are possible :

1 - The parameters of the initial solution are introduced at the prompt or by the commands file. Call the block **INIT(real,real,...,real)** and fill, if required, the initialization parameters table (real numbers) which follows.

2 - The initial solution is stored in a file (see **Degrees of freedom file**). Define the variables **MFIL**, **MINI**, **FFINI** and **TASINI**. Call the block **INIT(real,real,...,real)**.

Example 1:

The initialization is done without data files and all the degrees of freedom are set at zero ; the command is :

```
INIT[0]
```

If parameters (3 in this example) have to be specified, the command is :

```
INIT[0](1.0,-2,100)
```

Example 2:

The stationary initial solution is stored in the ASCII file `test.deb` ; the command is :

```
_MFIL='test'
_MINI='.deb'
INIT[0]
```

If the file is in binary format, the command is :

```
_MFIL='test'
_MINI='.deb'
_FFINI='BIN'
INIT[0]
```

In the transient context, the time has to be specified if the initial solution stored in binary format varies with time, for example load the solution associated with t=3h00 :

```
_MFIL='test'
_MINI='.deb'
_FFINI='BIN'
_TASINI=10800.
INIT[0]
```

Remark**{** XE "Remarque" **}** : The format of the file read by the block INIT is identical to the format generated by the block **FIN**.

Read the boundary conditions

The boundary conditions are stored in an ASCII file (see **Boundary conditions file**). Define only the variables **MFIL** and **MCND** to assign the file name in the stationary context. In the transient context, add **TASCND {** XE "transitoire" **}**. Call the block **COND**.

Example :

the stationary boundary conditions are in the file `test.prn` ; the command is :

```
_MFIL='test'
_MCND='.cnd'
COND[0]
```

In the transient context, the time has to be specified if the boundary conditions vary with time, for example load the conditions associated with t=1h00 :

```
_MFIL='test'
_MCND='.cnd'
_TASCND=3600.
COND[0]
```

Read the concentrated solicitations

The concentrated solicitations are stored in an**{** XE "sollicitations :concentrées" **}** ASCII file (see **Solicitations file**). Define only the variables **MFIL** and **MSLC** to assign the file name in the stationary context. In the transient context, add **TASSLC{** XE "transitoire" **}**. Call the block **SOLC**.

Example :

The stationary concentrated solicitations are in the file**{** XE "sollicitations :concentrées" **}** `test.slc` ; the command is :

```
_MFIL='test'
_MSLC='.slc'
SOLC[0]
```

In the transient context, the time has to be specified if the concentrated solicitations vary with time, for example load the solicitations associated with t=-0h30 :

```
_MFIL='test'
_MSLC='.slc'
_TASSLC=-1800.
SOLC[0]
```

Read the distributed solicitations

The distributed solicitations are stored in an**{** XE "sollicitations :concentrées" **}** ASCII file (see **Solicitations file**). Define only the variables **MFIL** and **MSLR** to assign the file name in the stationary context. In the transient context, add **TASSLR{** XE "transitoire" **}**. Call the block **SOLR**.

Example :

The stationary distributed solicitations are in the file**{** XE "sollicitations :concentrées" **}** `test.slr` ; the command is :

```
_MFIL='test'
_MSLR='.slr'
SOLR[0]
```

In the transient context, the time has to be specified if the distributed solicitations vary with time, for example load the solicitations associated with t=0h00 :

```
_MFIL='test'
_MSLR='.slr'
_TASSLR=0.
SOLC[0]
```

Solve the problem

The procedure to activate the solution has two steps :

1 - Mandatory step if **IMPR=**3. Assign a value to **ILU** and to **DELPRT**. Activate the block **PRCO**.

2 - Assign a value to **TINI**, NPAS, **IMPR**, **NPREC**, **NRDEM**, **NITER**, **OMEGA** and **EPSDL**. Call the block **SOLV(real,real,real)** and fill, if wanted, the limitors table which follows.

Example 1:

We want to run a stationary solution with a ILU matrix filled at level**{** XE "niveau :remplissage ILU" **}** 0, 1 preconditioning, 10 restarts, 25 iterations, a precision of 10-6 and limitors on the variation of velocities in x and y of 0.25m/s and of 0.1m on the water level ; the command is :

```
_ILU=0
_DELPRT=1.e-08
PRCO
_IMPR=3
_NPREC=1
_NRDEM=10
_NITER=25
_OMEGA=1.0
_EPSDL=1.e-06
SOLV[0](0.25,0.25,0.1)
```

Example 2:

We want to run a transient solution by an implicit Euler scheme**{** XE "transitoire" **} {** XE "Euler" **}** (ALFA=1) to simulate a one hour process with a one minute time step, and the simulation launch time set at 0. We use an ILU matrix filled at level**{** XE "niveau :remplissage ILU" **}** 0, 1 preconditioning, 10 restarts, 25 iterations, a precision of 10-6 and limitors on the variation of

velocities in x and y of 0.25m/s and of 0.1m on the water level ; the command is :

```
_ILU=0
_DELPRT=1.e-08
PRCO
_ALFA=1
_TINI=0
_DPAS=60
_NPAS=60
_IMPR=3
_NPREC=1
_NRDEM=10
_NITER=25
_OMEGA=1.0
_EPSDL=1.e-06
SOLV[0](0.25,0.25,0.1)
```

Remark**{** XE "Remarque" **}** : The intermediate solutions are not accessible in post-solution ; only the final solution can be exploited later.

Print the results

The print operation of each type of results consists in defining the name of the results file**{** XE "fichier:résultats" **}** (see **Structure of file names**) with the appropriate variables, and activating the appropriate block to proceed with the printing. Here are the various types of results that can be printed by HYDROSIM :

- Print the degrees of freedom
- Print the estimate of the numerical errors
- Print the post-processing
- Print the residuals
- Print the function current

Print the degrees of freedom

The degrees of freedom are stored in a binary file (see **Degrees of freedom file**). Define the variables **MFIL** and **MFIN** to assign the file name. Call the block **FCRT**.

Example :

The degrees of freedom must be stored in the ASCII file `test.fin` ; the command is

```
_MFIL='test'
_MFIN='.fin'
FIN[0]
```

or in a binary file

```
_MFIL='test'
_MFIN='.fin'
_FFFIN='BIN'
FIN[0]
```

Remark**{** XE "Remarque" **}** : The format of the file generated by the block FIN is identical to the format read by the block **INIT(real,real,...,real)**.

Print the estimate of the numerical errors

The numerical errors are stored in an ASCII file (see **Numerical errors file**). Define the variables **MFIL** and **MERR** to assign the file name. Call the block **ERR**.

Example :

The numerical errors must be stored in the file `test.err` ; the command is :

```
_MFIL='test'
_MERR='.err'
ERR[0]
```

Print the post-processing

The post-processing is stored in an ASCII file (see **Post-processing file**). Define the variables **MFIL** and **MPST** to assign the file name. Call the block **POST**.

Example :

The results of the post-processing must be stored in the file `test.pst` ; the command is :

```
_MFIL='test'
_MPST='.pst'
```

```
POST[0]
```

Print the residuals

The residuals are stored in an ASCII file (see **Residuals file**). Define only the variables **MFIL** and **MRES** to assign the file name in the stationary context. In the transient context, add DPAS and ALFA**{** XE "transitoire" **}**. Call the block **RESI**.

Example 1:

The residuals associated with a stationary solution must be stored in the file `test.res` ; the command is :

```
_MFIL='test'
_MRES='.res'
RESI[0]
```

Example 2:

The residuals associated with a transient solution calculated with an implicit **EULER** scheme (**ALFA**=1) and a one minute time step, must be stored in the file `test.res` ; the command is :

```
_MFIL='test'
_MRES='.res
_ALFA=1.0
_DPAS=60.'
RESI[0]
```

Print the function current

The function current is stored in a read/write ASCII file (see **Function current file**). Define the variables **MFIL** and **MFCR** to assign the file name, and the solution variables **ILU**, **NRDEM**, **NITER**, **EPSDL** and **OMEGA**. Call the block **FCRT**.

Example 1 :

The function current, after having been calculated by a direct method, must be stored in the file `test.fcr` ; the command is :

```
_MFIL='test'
_MFCR='.fcr'
_ILU=-1
_NRDEM=1
_NITER=1
```

```
_OMEGA=1
_EPSDL=1.E-06
FCRT[0]
```

Example 2 :

The function current, after having been calculated by an iterative method, economical in terms of memory space, must be stored in the file `test.fcr` ; the command is :

```
_MFIL='test'
_MFCR='.fcr'
_ILU=0
_NRDEM=25
_NITER=100
_OMEGA=1
_EPSDL=1.E-06
FCRT[0]
! call several FCRT if the problem did not
! converge
```

Remark : The result file associated with FCRT is a read/write file. If the file already exists before calling FCRT, you must make sure that the information it contains is conform (see **Function current file**). It should contain the initial solution of the function current.

Chapter 4 How to obtain a hydrodynamic solution?

This chapter provides precautions that should be observed to obtain a hydrodynamic solution in the best delays.

Past experience has shown that hydrodynamic modeling by finite elements is not a linear process, but rather an iterative procedure which should converge. A simulation is a complex activity which implies the construction of a terrain numerical model, a hydrodynamic mesh and boundary conditions. Then the model must be given an initial run, the solution processed and analyzed and the model validated. The following step, the most delicate, is to calibrate the model. When all these steps have been achieved, the model can be used as a prediction tool..

We will concentrate on certain dispositions which deserve to be consulted to execute a hydrodynamic simulation efficiently:

- How to validate the input data (preliminary phase)?
- How to give the model an initial run?
- How to converge the solution?
- How to validate the model?
- How to adjust the model (calibration)?
- Frequently asked questions

How to validate the input data (preliminary phase)?

"Input data" are the data transmitted directly to the simulator in the command file. These are not the basic terrain data used to build the terrain numerical model. They must be controlled directly by the software used to prepare the input data for HYDROSIM. In practice, you must make sure that :

1 - the finite element used for the mesh is available in the library of elements of HYDROSIM ;

2 - the skin of the hydrodynamic mesh represents the exact outline of the simulation domain ;

3 - the hydrodynamic mesh covers the entire flow bed ;

4 - the projection of the terrain numerical model on the hydrodynamic mesh does not generate corrupted values ;

5 - you launch a simulation with HYDROSIM with the instructions to read the data and print the post-processing ;

6 - you analyze the solution and verify if it respects the boundary conditions and the initial conditions.

How to give the model an initial run?

The initial run must calculate the very first solution on the simulation domain**{** XE "solution" **}**. It is an important step because, in certain cases, this first solution may become the initial solution to search for other states. This is especially the case when modeling long river reaches with a with a strong slope (water level difference of several meters).

For a successful initial run of the model, boundary conditions and initial conditions must be chosen with great care :

- Scenarios of boundary conditions
- Scenarios of initial conditions

Scenarios of boundary conditions

The boundary conditions are introduced on the outline of the simulation domain, i. e. on the mesh skin. Physically, the domain outline is formed by a series of open and solid boundaries. Each type of boundary requires a special treatment :

- Solid boundary
- Open boundary

Solid boundary

On a solid boundary (shore), the water level is never imposed. However, one or the other of the following conditions is introduced :

- q_n = 0 (normal flux nil at the boundary or impermeability condition**{** XE "conditions :imperméabilité" **}**)
- $q_n = q_t = 0$ (the normal and tangential components of the flux are nil or no flow conditions**{** XE "conditions :adhérence" **}**)

In practical studies of rivers, an impermeability condition is more appropriate because it ignores the limit layer developing along solid boundaries. A limit layer is subjected to strong gradients and it is very thin compared to the dimensions of the study domain. Very often, this small zone offers little interest to the model designer.

However, in the case where the flow is confined to a cavity, a groin or around a stopping point, a no flow condition is then required.

Remember that a limit layer badly captured (use of a no flow condition on a coarse mesh) will result in artificially slowing down the flow and over elevating the water level. If the modeling exercise is to reproduce the limit layer, the mesh must be refined in the normal flow direction{ XE "couche limite" }.

Remark{ XE "Remarque" } : The condition of nil flux on a solid boundary is implicit in HYDROSIM and does not have to be specified explicitly.

Open boundary

On a downstream open boundary, the water level is always imposed{ XE "niveau :aval" }. The direction of flow can be imposed via the tangent flux, or kept free :

- $h = h_{aval}$
- $q_t = 0$ (tangential component of nil flux) or free

In sub-critical flow regime{ XE "régime :fluvial" } (Froude Number{ XE "Froude" } < 1), on an upstream open boundary, we always impose either the water level or a solicitation in discharge, and eventually, the direction of flow :

- $h = h_{amont}$, a solicitation in normal flux q_n.
- $q_t=0$ (tangential component of nil flux)

while in rapid flow{ XE "régime :torrentiel" } (Froude{ XE "Froude" } Number > 1), the water level and the normal flux must be imposed :

- $h=h_{amont}$
- $q_n=q_{n\ amont}$ (normal component of the imposed flux)

The conditions on the flux were expressed in the normal-tangent { XE "repère" } coordinate system because it is the most appropriate, in the sense that it reflects the most simply the flow conditions. Only in very theoretical cases is it possible to fix conditions on the flux in a cartesian coordinate system mixed ({ XE "repère" }to within a 90 degree rotation) with the normal-tangent system{ XE "repère" }.

A solicitation applies when the degree of freedom is not imposed explicitly, In certain cases, it can be an advantage since the resulting system of finite element equations is less constrained and more friendly for the solution procedure.

Remark{ XE "Remarque" } : The water level imposed has precedence over the solicitation on discharge, if they are imposed at the same time on a same boundary.

Scenarios of initial conditions

The initial conditions must be chosen with great care to ensure the delicate{ XE "conditions :initiales" } convergence{ XE "convergence" } of the solution process. In HYDROSIM, four (4) strategies of initialization are proposed :

- Static solution (static water body)
- Quasi linear solution
- Improved quasi-linear solution
- Reference solution

Static solution (static water body)

In this situation, the fluid is resting ; the expression for the entire domain is :

- $q_{x0}=q_{y0}=0$
- h_0=constant

Example :

The HYDROSIM command file is :

```
! no initialization file to read
!_MINI=''
INIT(0.0 ,0.0 , constant, 0.0, 0.0, 0.0, 0.0)
```

This form can be sufficient when the slope in the modelized domain is weak (a few centimeters at most). The choice of the value given to h is generally consistent with the water level imposed at the open boundaries.

Quasi linear solution

In this situation, the water level and the slope are roughly known *a priori.* At all points of the simulation domain, the water level is given by the equation of a flat surface :

- $h(x)=h_0+S_x(x-x_0)+S_y(y-y_0)$

where h_0 is the water level at the coordinate (x_0,y_0). S_x and S_y are the slopes in x and y respectively.

The flux are approximated by the program using the Chézy{ XE "Chézy" }-Manning law{ XE "Manning" } :

- $q_{xi}=(S_{xi}/(S_x^2+S_y^2)^{0,25}).(H^{5/3}).(1/n)$, i=1,2

where H represents the depth and n the Manning coefficient{ XE "Manning" }.

Example :

The command file is :

```
! no initialization file to read
!_MINI=''
INIT(0.0 ,0.0 , h0, Sx, Sy, x0, y0)
```

This form can be very interesting in straight channel since it accelerates the convergence process if the initial solution is near the solution of the problem.

Warning{ XE "Mise en garde" } : in rivers, this approach is not desirable since it does not take into account the complexity of the stream and thalweg profile. The lack of pertinence of the predicted initial solution may compromise the convergence process.

Improved quasi-linear solution

It is a generalization of the approach Quasi linear solution in the sense that the water level and the slopes are known *a priori*. The approximation of flux is the same as in the quasi-linear solution.

However, the difference is that the slopes are variable in the simulation domain. In this case, the initialization must be done from a n initialization file. The information must contain the water level values and the flux set at zero (see file format).

Example :

The command file is :

```
! initial solution stored in file 'sol-
initiale.deb' in format ASCII
_FFINI='ASCII'
_MINI='sol-initial.deb'
INIT
```

This form of initialization is very interesting as it offers an appreciable calculation time saving in the large scale modeling projects.

Reference solution

The solution proceeds from a simulation previously conducted. It is the case when conducting a sensitivity study (to discharge or to regulated conditions) and wanting to switch from one state to another.

Example :

The command file is :

```
! initial solution stored in file
```

```
! 'sol-reference.deb' in format ASCII
_FFINI='ASCII'
_MINI='sol-reference.deb'
INIT
```

This form of initialization is practical when attempting to reach solution convergence with several steps. It can also be useful when moving from one event to another by slightly modifying the hydraulic data.

How to converge the solution?

- Solution method
- Solution update
- Behaviour of the solver
- Has convergence been reached?
- Advanced solution strategies
- Practical advice

Solution method

In HYDROSIM, the solution method of the algebraic equation system is done by the iterative non-linear GMRES method, according to a "Newton-Inexact" scheme, with preconditioning. The different aspects of the method are :

- GMRES
- Preconditioning matrix
- Memory space
- Precision

GMRES solution algorithm

The functioning of the GMRES**{** XE "GMRES :algorithme" **}** solution algorithm is presented on Figure 1. There are three loops. The first loop is driven by the variable **NPREC**, the second by the variable **NRDEM** an the third by **NITER** which cannot exceed the value of TNDF**{** XE "NDLT" **}**, the total number of degrees of freedom (variable). The variable NITER plays a double role as, not only does it fix the number of iterations, but it

also governs the dimension of the solution sub-space equal to the product of NITER by TNDF**{** XE "NDLT" **}**.

The first loop is dedicated to the calculation of the Preconditioning matrix, the second to the Solution update and the third to the calculation of the solution sub-space of the type Krylov by the GMRES**{** XE "GMRES :paramètres" **}** method.

The functioning parameters are :

1 - the number of preconditioning NPREC

2 - the number of restart NRDEM

3 - the number of iterations NITER

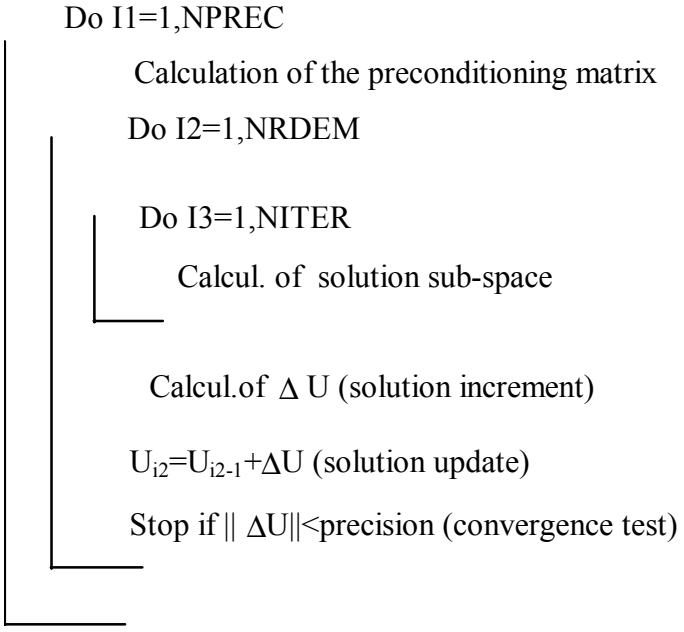
The theory stipulates that for a linear problem, the GMRES**{** XE "GMRES :théorie" **}** algorithm converges at a maximum of TNDF**{** XE "NDLT" **}** iterations, which would be totally impossible in practice because of the exorbitant Memory space required for a normal problem. However, in a non-liner case, there are no methods to determine the optimal values of the functioning parameters. Experience on a wide range of problems suggest the following default values :

```
_NPREC=1
_NRDEM=25
_NITER=25
```

The number of preconditioning (NPREC*) can be* increased for important simulations.

The stop criteria of the algorithm is based on the increment norm, i. e. the progress of the solution which must be below the Precision fixed by the variable **EPSDL**.

Figure 1 : Non-linear GMRES solution algorithm.



Preconditioning matrix

The preconditioning matrix plays a very important role in the GMRES solution algorithm**{** XE "GMRES :préconditionnement" **}**. A good preconditioning greatly improves the performances of the solver. For example, two given preconditioning matrix can make the problem either converge or diverge. There is divergence of the solution algorithm if the increment norm tends to increase (explosion).

In the case of the Saint-Venant equations**{** XE "Saint-Venant" **}**, the experience shows that the ILU preconditioning matrix, with minimum fill level (ILU=0), is efficient. The command file :

```
_ELTYP='SVCRNM'
:
_ILU=0
PRCO
_IMPR=3
:
```

If the Memory space allows it, better results are obtained with the maximum fill level (ILU=-1). In this case, to minimize calculation and memory requirements (related to the matrix band width), the commands are :

```
ELTYP='SVC'
:
_ILU=-1
PRCO
_IMPR=3
:
```

In the case when even a ILU matrix with the minimum fill level**{** XE "niveau :remplissage ILU" **}** (ILU=0) cannot be exploited because of memory capacity problems, the compromise to make is to use a diagonal preconditioning (see **IMPR**).

Remark**{** XE "Remarque" **}** : The performance of the ILU preconditioning is strongly influenced by the numbering of the mesh nodes. To obtain better results, it is recommended to use a numbering algorithm minimizing the band width.

Memory space

In the solution algorithm, the **ILU** preconditioning matrix and the dimension of the solution sub-space via **NITER** determine the memory space required for the solution procedure..

The memory space needed to store the ILU matrix with a n fill level (ILU=n) is about :

$$\sigma.((3/2).NKGP\{ XE "NKGP" \}+(3.n+1).NDLT\{ XE "NDLT" \}+1/2)$$

in Megabytes{ XE "mégabytes" } ;

while that associated with the solution sub-space is given by :

$$\sigma.NITER.NDLT\{ XE "NDLT" \}$$

where $\sigma=8/2^{20}$ is the conversion coefficient from real words to Megabytes and NKGP{ XE "NKGP" } the number of non-null terms in the ILU matrix. This information can be found in the output file associated with the command :

```
_ILU=0
PRCO[0]
```

Precision

The precision applicable to the iterative process of the Solution update is defined using the variable **EPSDL**. The greater the precision, the greater the volume of calculation.

For the simulation of theoretical problems, EPSDL is given a value in the order of :

```
_EPSDL=1.E-10
```

For the efficient simulation of real cases, the value temporarily given is the order of :

```
_EPSDL=1.E-03
```

and, nearing the solution, the value of{ XE "solution" } EPSDL is progressively reduced to the desired precision Which may typically be in the vicinity of :

```
_EPSDL=1.E-06
```

Solution update

In the solution algorithm (see Figure 1), the solution updte is done after each restart, as follows ::

$$U_{i2}=U_{i2-1}+\Delta U$$

where U_{i2} designates the vector solution at the (i2) th restart and ΔU the solution increment.

However, HYDROSIM proposes to modulate the solution update, which may be very useful when the solution varies greatly and/or the non-linearities are important. The calculation of the solution increment ΔU is as follows :

$$\Delta U= signe(\Delta U)\ max(\Delta U_{max},|\omega\Delta U|)$$

where ΔU_{max} is the limitor. A limitor is associated with each type of variable (degree of freedom).

Therefore, two possibilities are offered to intervene during the solution update :

- Relax the solution update
- Limit

Relax the solution update

To relax the solution means "to tone down" the amplitude of the increment ΔU. The procedure of the solution update is as follows :

$$U_{i2}=U_{i2-1}+\omega\Delta U$$

where ω is the relaxation factor.

Example :

We want to sub-relax the solution with a factor of 0.8 :

```
_OMEGA=0.8
```

In practice, the sub-relaxation (ω<1) allows the solver to better converge when the problem is difficult. On the other hand, it slows down the solution process, especially when nearing the solution..

Limit the solution update

The technique consists in imposing an absolute limit to the value of the increment ΔU.

Example :

We want to limit the solution update ΔU with values of ΔU_{max} of 0.25 and 0.1 on the flux (q_x,q_y) and the water level (h) respectively :

```
SOLV[0](0.25, 0.25, 0.1)
```

In practice, the limitor intervenes in the solution update process only when the increment ΔU exceeds the limitor ΔU_{max}. Also, nearing the solution, the solution process is not slowed down.

The limitation of the solution update can be done along with the relaxation.

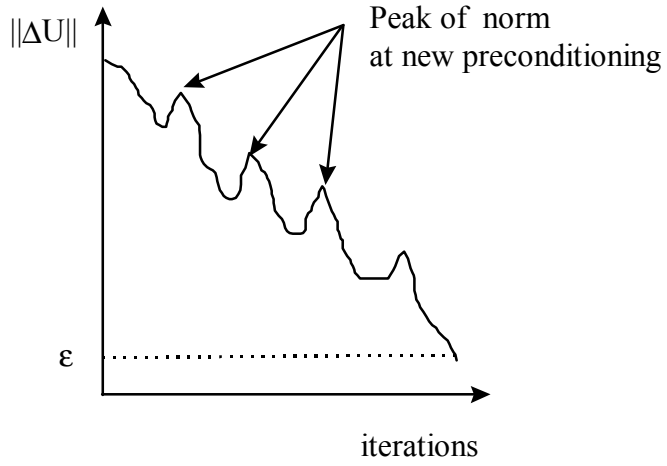
Behaviour of the solver

Figure 2 presents the typical convergence curve of**{** XE "convergence" **}** GMRES**{** XE "GMRES :comportement" **}** associated with a preconditioning of the type **ILU**.

In general, there is a peak of the norm of**{** XE "norme" **}** ΔU at each update of the ILU matrix, in other words at each new preconditioning.

The convergence**{** XE "convergence" **}** of the problem is reached according to the precision ε retained, if at the following preconditioning, the peak of the norm remains inferior to ε (see Has convergence been reached?).

Figure 2 : Typical behaviour of the norm of the solution increment ΔU as a function of the iterations in the case of GMRES with the ILU preconditioning matrix.

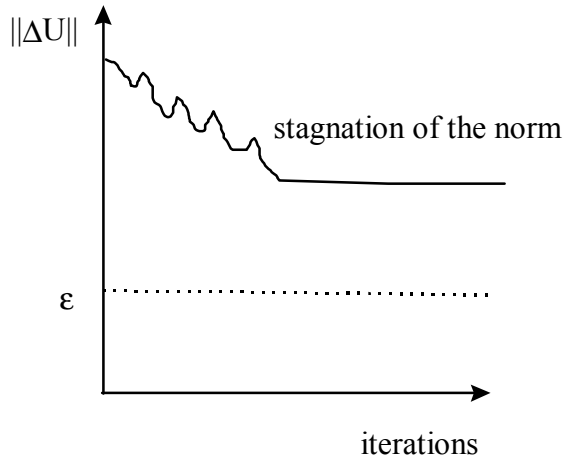


In certain cases, GMRES may stagnate or oscillate**{** XE "GMRES :stagne" **} {** XE "GMRES :oscille" **}**(Figure 3). The first possible cure is to increase the number of iterations **NITER**. Not only does this parameter extend the calculation loop, it also increases the solution sub-space.

If the result is the same, modify the upper bound of viscosity upward first, then downward if necessary**{** XE "viscosité :borne" **}**.

If the problem persists, it is likely that the solution cannot be found because of a lack of discretization somewhere in the simulation domain. You must then visually identify the problem zone (zone with high residuals). Next, you must refine the mesh locally and re-launch the simulation.

Figure 3 : Stagnation of the convergence process of the norm.



Has convergence been reached?

To confirm that the convergence of the calculated solution has been reached numerically, you must make sure that :

1 - GMRES has converged ;

2 - The norm of the residuals associated with each degree of freedom**{** XE "norme" **}** (q_x, q_y et h) is at most in the same order as ε.

If there is convergence, the**{** XE "convergence" **}** simulation is ended.

In the case of local convergence only, the simulation must be re-launched starting from the last solution, and the number of iterations **NITER** must be increased. Repeat this procedure if needed.

If the problem persists, visually analyze the results ; two scenarios are possible :

1 - The results are generally valid. In this case, isolate the zones with high residuals. Refine the mesh in these zones, re-launch the simulation on this new mesh. Repeat this procedure, if needed.

2 - Locally, the results are bad (velocity vectors shooting in all directions, parasitic oscillations of the water level). In this case, you must re-launch the simulation with a new initialization :

   a) by increasing the upper bound of viscosity if the problem zone is located in the flow bed**{** XE "viscosité :borne" **}**.

   b) by decreasing the upper bound of viscosity if the problem zone is located near the shore.

Advanced solution strategies

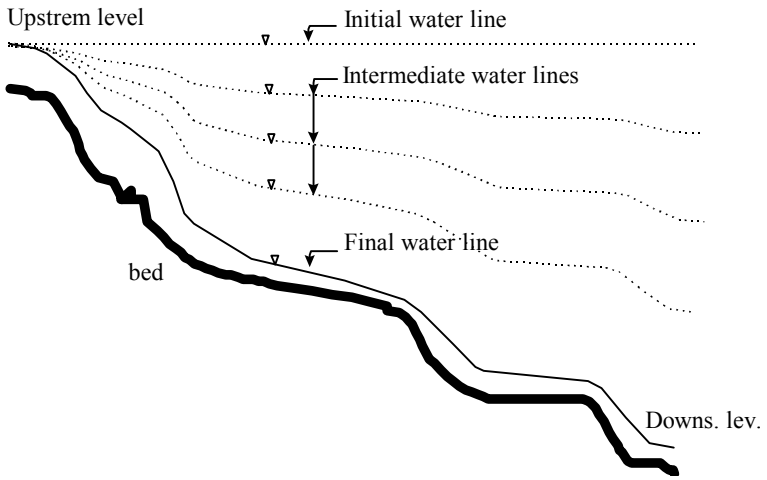
In certain cases, the solution of the problem is not automatic. You must then adopt a solution strategy using intermediate solutions. The choice of the strategy is on a case by case basis. Four solution strategies have been identified.

- Driven by the downstream water level
- Driven by the convective acceleration (inertia)
- Driven by the upper bound of viscosity
- Driven by the time step

Driven by the downstream water level

This strategy is generally used in the phase of the initial run of the model, during modeling of small streams or long river reaches (several km), where the water level difference between the upstream and downstream boundaries is in meters as shown on Figure 4.

Figure 4 : : Successive water lines on a profile.



The boundary condition on the downstream water level is the parameter to modify.

Example :

The upstream water level is at the elevation**{** XE "niveau :amont" **}** 155 m and the downstream level targeted at the elevation 150 m. We begin with a downstream level of 155 m. To calculate the solution in permanent regime, we intend to modify the downstream level by increment of -0.50 m. The command file reads :

Beginning of the command file for the first simulation driven by the downstream water level **{** XE "niveau :aval" **}**

```
:
_ELTYP='SVCRNM'
_STEMP='STATIQ'
FORM
:
! Initial condition :Initial model run
INIT[0](0.0, 0.0, 155.0, 0.0, 0.0, 0.0, 0.0)
! Downstream condition h=154.5m
_MCND='haval_154p5.cnd'
COND[0]
:
! Printing of the degrees of freedom
_MFIN='haval_154p5.deb'
FIN
STOP
! End of the command file of the first
simulation
```

Beginning of the command file for the second simulation driven by the downstream water level **{** XE "niveau :aval" **}**

```
:
_ELTYP='SVCRNM'
_STEMP='STATIQ'
FORM
:
! Initial condition :Solution of the first
simulation
_MINI='haval_154p5.deb'
INIT[0]
! Downstream condition h=154,0m
_MCND='haval_154p0.cnd'
COND[0]
:
! Printing of the degrees of freedom
_MFIN='haval_154p0.deb'
FIN
STOP
! End of the command file of the first
simulation
```

We repeat until the downstream water level reaches the elevation 150 m.

Remark{ XE "Remarque" }: Another possibility would be to automate all the operations described above by inserting them in a single command file.

If the solution does not converge, reduce the water level increment.

Driven by the convective acceleration (inertia)

The convective acceleration (inertia) is the component of the movement equation associated with the changes in the flow section (sills, pools, bridge section, etc...). The influence of convective acceleration on the convergence problems is major, especially when the flow regime is near critical or supra-critical conditions. To by-pass the difficulty, the solution is calculated in successive steps by gradually increasing the effects of the convective acceleration on the intermediate solution. This procedure is known as convective acceleration driven solution, where the activation factor of the convection varies in the range [0,1]. Inertia is inactive when the factor is equal to 0 (Stokes problem{ XE "Stokes" }) and completely activated at 1.

Example :

The upstream water level is at elevation 155 m and the downstream water level is at 150m. To calculate the solution in permanent regime, we choose the approach « Driven by the downstream water level » and the level of activation of the convection in the phase of downstream water level reduction remained at 0. The solution obtained is stored in the degrees of freedom file `haval_150p0.deb`. Next, we add the effects of convection by increments of 0.25. The command file reads :

Beginning of the command file of the first simulation driven by activation of the convective acceleration

```
:
_ELTYP='SVCRNM'
_STEMP='STATIQ'
FORM
:
! Convection factor equal to 0.25
PRGL[0](9.8, 0., 0., 1., 0.,1.e-6 ,100, 10.,1., 0.25,0.5,1e-05,1e-3)
:
! Initial condition :Solution with haval=150,0m and convection
! null.
_MINI='haval_150p0.deb'
INIT[0]
```

```
:
! Printing of the degrees of freedom
_MFIN='haval_150p0_conv_0p25.deb'
FIN
STOP
! End of the command file of the first
simulation
```

Beginning of the command file of the second simulation driven by activation of the convective acceleration

```
:
! Convection factor equal to 0.50
PRGL[0](9.8, 0., 0., 1., 0.,1.e-6 ,100, 10.,1.,
0.50,0.5,1e-05,1e-3)
:
! Initial condition :Solution of the first
simulation
_MINI='haval_150p0_conv_0p25.deb'
INIT[0]
:
! Printing of the degrees of freedom
_MFIN='haval_150p0_conv_0p50.deb'
FIN
STOP
! End of the command file of the second
simulation
```

We proceed like this until the convection level reaches 1.0.

Remark**{** XE "Remarque" **}**: Another possibility would be to automate all the operations described above by inserting them in a single command file.

If the solution does not converge, reduce the increment of the convective acceleration.

Driven by the upper bound of viscosity

The term turbulent diffusion in the equations takes into account the constraints of shear stress and of compression related to the gradients of velocity in the flow (vicinity of a strong current, or zone of lentic water, for example). The turbulent viscosity is the key parameter of this term of equilibrium, and it is automatically calculated HYDROSIM. However, it can be useful to modify its value to improve convergence of the solution.

The calculation of a stable solution in permanent regime is achieved by giving a high value to the upper bound of the viscosity. The effect of an excessive viscosity is to artificially

inflate the water level and to smoothen the flow by masking its complexity. The objective is then to progressively decrease the value of the upper bound to an acceptable value. However, by releasing the complexities of the flow (e. g. re-circulation), convergence is made more difficult. In fact, mesh size may hinder the possibility of solving a complex flow structure. It is admitted that the minimum value of the upper bound of viscosity is the limit of convergence.

The value given to launch the very first simulation is empirical.

Example :

The upstream water level is at elevation 155 m and the downstream water level is at 150m. To calculate the solution in permanent regime, we choose the approach « Driven by the downstream water level », maintaining the upper bound of viscosity at a value of 100 m^2/s during the phase of water level reduction. The solution obtained is stored in the degrees of freedom file `haval_150p0_nusup_100p0.deb`. Next, we reduce the value of the upper bound of viscosity by increment of 10 m^2/s. The command file reads :

Beginning of the command file of the first simulation driven by the upper bound of viscosity

```
:
_ELTYP='SVCRNM'
_STEMP='STATIQ'
FORM
:
! Upper bound of viscosity equal to 90
PRGL[0](9.8, 0., 0., 1., 0.,1.e-6 ,90, 10.,1.,
1.0,0.5,1e-05,1e-3)
:
! Initial condition :Solution calculated with
the upper bound
! of viscosity equal to 100
_MINI='haval_150p0_nusup_100p0.deb'
INIT[0]
:
! Printing of the degrees of freedom
_MFIN='haval_150p0_nusup_90p0.deb'
FIN
STOP
! End of the command file of the first
simulation
```

Beginning of the command file of the second simulation driven by the upper bound of viscosity

```
:
```

```
! Upper bound of viscosity equal to 80
PRGL[0](9.8, 0., 0., 1., 0.,1.e-6 ,80,
10.,1.,1.0,0.5,1e-05,1e-3)
:
! Initial condition :Solution of the first
simulation
_MINI='haval_150p0_nusup_90p0.deb'
INIT[0]
:
! Printing of the degrees of freedom
_MFIN='haval_150p0_nusup_80p0.deb'
FIN
STOP
! end of the command file of the second
simulation
```

We proceed like this until convergence becomes difficult, or that the degree of adequation with the available measurements (validation{ XE "validation" }) is satisfactory.

Remark{ XE "Remarque" } : Another possibility would be to automate all the operations described above by inserting them in a single command file.

If the solution does not converge, reduce the increment of the upper bound of viscosity.

A possible consequence of the reduction of the upper bound of viscosity is the degradation of mass conservation.

Driven by the time step

A permanent flow can be solved in time if the transient phase has no interest. The stationary solution is sought for with this method.

Example :

The upstream water level is at elevation 155 m and the downstream water level is at 155 m. We start from a hydrostatic initial condition with a water body at elevation 155 m. To calculate the solution in permanent regime, we vary the downstream water level at the rate of 0.50 m per hour. It would take 10 hours for the downstream water level to reach 150 m and about 5 more hours for the flow to reach a permanent regime. With a time step of 900 s, a minimum of 660 simulation time step is needed. The command file reads :

Beginning of the command file of the simulation driven by the time step { XE "pas de temps" }

```
:
_ELTYP='SVCRNM'
_STEMP='EULER'
```

```
FORM
:
! Initial condition :Model initial run
INIT[0](0.0, 0.0, 155.0, 0.0, 0.0, 0.0, 0.0)
! Downstream condition h=155.0m à t=0h00 et
150.0m à t=10h00.
! Downstream water level at beginning 155.0m
_TASCND=0
_MCND='hav_155p0_t00h00-150p0_t10h00.cnd'
COND[0]
:
! parameters of solution in time
_TINI=0
_DPAS=900
_NPAS=100
:
STOP
! End of command file
```

Remark{ XE "Remarque" } : If the solution does not converge, reduce the time step{ XE "pas de temps" }. If the problem persists, reduce the rate of downstream water level reduction.

Practical advice

This advice concerns long duration simulations, for example a night long job. To avoid any unexpected problem which might induce the loss of several hours of calculation, it is strongly recommended to print periodically the degrees of freedom, in different files if disk space is available. After a power failure, it will be possible to re-launch the simulation from the most recent solution obtained or acceptable.

Example :

For a same volume of calculation, instead of command 1 :

```
!---- command 1 : single printing of dof in
test.fin
_NPREC=3
SOLV[0](0.25,0.25,0.1)
_MFIL='test'
_MFIN='.fin'
FIN[0]
```

use :

```
!---- command 2 : periodical printing of dof in
test.fin#i.
_MFIL='test'
_NPREC=1
SOLV[0](0.25,0.25,0.1)
_MFIN='.fin#1'
FIN[0]
SOLV[0](0.25,0.25,0.1)
_MFIN='.fin#2'
FIN[0]
SOLV[0](0.25,0.25,0.1)
_MFIN='.fin#3'
FIN[0]
```

How to validate the model?

A converged solution is not necessarily valid ; in other words, the solution calculated may lack objectivity. The validation procedure intends to verify the degree of similarity between the terrain observations and the simulation results under the same hydrodynamic conditions.

For example, in a lake where the slope is very gentle (in the order of 10^{-6} to 10^{-5} m/m), a difference of 10 cm between the simulated levels and the values observed may not be acceptable. However, it would be a reasonable difference in a mountain stream with a much steeper slope (in the order of 10^{-3} to 10^{-2} m/m).

If the solution of initialization calculated is judged acceptable as first approximation, then we can move to the calibration step which, by various adjustments brought either to the terrain model or to the values of the model parameters, will refine the solution and bring it closer to actual measurements.

If, for any reason, the solution of initialization does not seem acceptable (unrealistic flow facies, excessively high or low water level, parasitic oscillations or extreme values of the hydrodynamic variables, for example), you must continue the exercise of initialization until satisfactory.

In addition to incoherent flow directions (arrows burst in all directions without any logic), you must make sure that :

1 - the terrain topography is properly represented on the hydrodynamic mesh ;

2 - in the case of very wide rivers, the Coriolis force, which applies perpendicular to movement to the right in the northern hemisphere and the opposite in the southern hemisphere, is taken into account**{** XE "Coriolis" **}** ;

3 - the wind strength , which accelerates, slows down or diverts the flow, is taken into account ;

4 - the presence of aquatic plants, which slow down the flow, is taken into account ;

5 - the surface ice cover, which reduces the depth and increases the flow velocity, is taken into account ;

6 - the transit discharge at boundary conditions level-level has the proper value (see Control of mass) ;

7 - the natural boundaries of the flow delineated by the isoline H=0 are correctly positioned ;

8 - flow is absent in « drying » zones (Control of Drying/Wetting).

If, after the necessary corrections, the systematic and unacceptable bias persists, then you should question the terrain data.

Control of mass balance

The mass balance gives a good idea of the quality, in terms of physics, of a solution. In the output file `result.out` in the block **POST**, HYDROSIM returns the error on the discharge over the entire simulation domain and gives the entering and outgoing discharges.

There could be a very good level of convergence, and yet a mediocre quality solution. To correct the problem, first identify the problem zones. This is done by viewing the local and global mass balance. Second, analyze the spatial distribution of the errors of mass conservation. Next, refine the zones judged deficient. Then, use the same solution strategy as on the preceding mesh.

The block of error estimates indicates if the solution may change by refining the mesh. The units of errors are identical to those of the variables to which they are associated : m^2/s for flux and m for the water level.

Control of Drying/Wetting

The Drying/Wetting model is governed by the penalization (strong increase) of the Manning coefficient in the dry zones.

Although non-significant, there always persists a form of flow in the dry zones. The penalization must be sufficiently high to reach this objective in the « drying » zones.

If after examining a solution, the discharge in the « drying » zones is found to be too high, the penalization value must be increased until the quality criteria desired is reached.

Example :

We consider a solution involving Drying/Wetting zones. The analysis of the solution obtained with a penalization coefficient of 10 reveals a significant flow in the dry zone. The solution stored in the file `sol_ref_penman_10p0.deb` is improved by increasing the penalization value of the Manning{ XE "Manning" } coefficient by increment of 5. The command file reads :

Beginning of the command file of the first simulation with Drying/Wetting adjustment{ XE "couvrant-découvrant" }

```
:
_ELTYP='SVCRNM'
_STEMP='STATIQ'
FORM
:
! Penalization value of Manning coefficient
equal to 15
PRGL[0](9.8, 0., 0., 1., 0.,1.e-6 ,100, 15.,1.,
1.0,0.5,1e-05,1e-3)
:
! Initial condition :Solution calculated with
penalization value of Manning coefficient equal
to 10
_MINI='sol_ref_penman_10p0.deb'
INIT[0]
:
! Printing of the degrees of freedom
_MFIN='sol_ref_penman_15p0.deb'
FIN
STOP
! End of command file of the first simulation
```

Beginning of the command file of the second simulation with Drying/Wetting adjustment{ XE "couvrant-découvrant" }{ XE "couvrant-découvrant" }

```
:
! Penalization value of Manning coefficient
equal to 20.
PRGL[0](9.8, 0., 0., 1., 0.,1.e-6 ,100, 20.,1.,
1.0,0.5,1e-05,1e-3)
```

```
:
! Initial condition :Solution of the first
simulation
_MINI='sol_ref_penman_15p0.deb'
INIT[0]
:
! Printing of the degrees of freedom
_MFIN='sol_ref_penman_20p0.deb'
FIN
STOP
! End of command file of the second simulation
```

We proceed like this until the flow reduction in dry zones is satisfactory.

Remark**{** XE "Remarque" **}** : Another possibility would be to automate all the operations described above by inserting them in a single command file.

If the solution does not converge, reduce the increment of the penalization of the Manning coefficient**{** XE "Manning" **}**.

How to adjust the model (calibration)?

This step finely adjusts the physical and numerical parameters to bring the numerical solution in concordance with the terrain data under the same hydrodynamic conditions. There are two steps to this operation ; adjustment of the target parameters, and control of the solution obtained versus the terrain measurements.

Depending on the objectives of the modeling, emphasis can be put on a specific variable of the problem : water level for flood studies ; water level and velocities for habitat studies or contaminant transport studies.

There are three calibration**{** XE "calibration" **}** procedures :

- Calibrate by the discharge
- Calibrate by the water level
- Calibrate by velocities

Calibrate by the discharge

In the case where the boundary conditions used are of the type level-level, we expect that the results of the model will correspond relatively well *a priori* to the measured water level. However there remains to make sure that the solution calculated

transits a discharge (see How to estimate the discharge transiting in the domain?) identical to the discharge measured in the field.

If we have good reasons to believe that the friction coefficients are acceptable in the state considered, and that the discharge observed and calculated are not sufficiently close (at the minimum the precision of the measure), the viscosity must be adjusted by moving the upper bound upward if the calculated discharge is overestimated, or downward if the discharge is underestimated.

Calibrate by the water level

To calibrate the water level, you must first have calibrated by the discharge (see Calibrate by the discharge) ;

Varying the water level is made by adjusting, in an acceptable range, the Manning coefficient**{** XE "Manning" **}**.

The water level will tend to rise if the Manning coefficient is increased, and conversely if it is decreased.

The variation of the water level will be more sensitive at greater flow velocities.

Calibrate by velocities

To calibrate by the velocities, you must have calibrated by the discharge and by the water level (see Calibrate by the discharge and Calibrate by the water level).

If there is a difference between the velocities measured vs calculated, the Manning coefficient must be adjusted**{** XE "Manning" **}**. When it is increased, the coefficient slows down the flow, reduces the flow velocity. Conversely, when decreased, the flow velocity increases.

Remark**{** XE "Remarque" **}**: The discharge and the water level may be influenced by this operation. Modifications to the friction coefficient must be done in a way that globally maintain the behaviour of the model toward these two variables. An increase of the friction coefficient in a region of the flow should be accompanied by an equivalent decrease elsewhere**{** XE "frottement" **}**.

Adjust the Manning coefficient upward or downward if the velocities are overestimated or underestimated respectively.

If the problem persists, make sure that :

1 - the hydrodynamic mesh is sufficiently fine to properly capture the terrain topography and its flow resistance properties ;

2 - at the point of control, the bottom elevation projected on the hydrodynamic mesh is identical to that measured in the field ;

3 - the mean velocity measured in the field is representative of the mean flow in the horizontal plane, and not the result of a singularity ;

4 - the mean velocity measured in the field was obtained from at least three points in the water column for bottoms non uniform grain size (the velocity measured at 0.4H above the bottom is not always equal to the mean velocity).

Frequently asked questions

- How to evaluate the turbulent viscosity?
- How to minimize the level of error?
- Has the solution diverge?
- What is numerical viscosity?
- What is the role of the upper bound of the viscosity?
- What are the effects of an excessive dissipation?
- How to estimate the discharge transiting in the domain?

How to evaluate the turbulent viscosity?

Evaluating the turbulent viscosity is always a delicate exercise since the theory on turbulence is still a very active and open field of research.

The software HYDROSIM proposes two classical approaches to quantify the effect of turbulence :

1 - the constant viscosity model ;

2 - the mixing length model**{** XE "longueur de mélange" **}**.

The model of the type mixing length seems to be closer to reality than the model of constant turbulent viscosity since it takes into account the local variability of the flow ; however the difficulty is transferred to the evaluation of the mixing length.

In practice, adjusting the turbulent viscosity is part of the model calibration process. When the problem centers on the use of the water level, the mixing length is not required**{** XE "longueur de mélange" **}**. However, if you wish to improve the representation of the velocities, this solution is recommended.

How to minimize the level of error?

Supposing that the model is well parameterized, the errors affecting the solution are directly related to the variability of the terrain data and of the geometry of the domain modelized. The mesh refinement procedure is intended to minimize the level of error to an acceptable proportion, as long as there are sufficient terrain data to support it.

To avoid useless mesh refinement, which would induce prohibitive calculation times, it is recommended to intervene locally, where the level of error is judged too important. The problem zones can be identified by the analysis of the distribution of residuals, of errors of numerical approximations and of mass balances.

Has the solution diverge?

The solution process has diverged if one or all of the following phenomena are observed :

1 - The norm of the increment of the solution tends to increase and even to explode ;**{** XE "norme" **}**

2 - the norm of the residuals explode ;

3 - the mass balance is not realistic ;

4 - over the entire domain, or locally, velocity vectors shoot in all directions ;

5 - over the entire domain, or locally, there are strong parasitic oscillations of the water level

What is numerical viscosity?

Numerical viscosity is an adjustment coefficient of pure numerical origin which as the dimension of a viscosity. Its role is to condition the system of equations finite elements to make sure that a solution exists when flow is dominated by convection**{** XE "convection" **}**.

The value given to numerical viscosity depends on the mesh and the flow conditions. In HYDROSIM, numerical viscosity is managed by the Peclet**{** XE "Peclet" **}** number set at 0.5. The variation of the numerical viscosity is inversely proportional to that of the Peclet number.

What is the role of the upper bound of the viscosity?

The upper bound of the viscosity controls the numerical and turbulent viscosity calculated during the solution process. An overestimation of the viscosity values could compromise the processus of convergence. On the opposite, an upper bound too low could also underestimate the level of dissipation and have the problem diverge quickly.

In practice, it is always difficult to set at the beginning of the very first simulation the value to give to the upper bound of viscosity. Only through a trial and error procedure can it be set properly.

What are the effects of an excessive dissipation?

The phenomenon of excessive dissipation is caused by an overestimation of the viscosity. An excessive dissipation will artificially inflate the water level and smoothen the flow. To improve the results, you can modify the upper bound of viscosity by decreasing it to the limit of convergence. This will result in reducing the water level and developing the complex structures of the flow as observed in real life.

How to estimate the discharge transiting in the domain?

The discharge transiting in the simulation domain is estimated by analyzing the results of the function current. For example, Figure 5 presents a tracing of isolines, known as lines of current, of the function current. Along a line of current, the normal flow is nil. Thus, it may be considered that a solid boundary represents a line of current because of the impermeability condition imposed. A constant portion ΔQ of the total discharge transiting in the domain flows between two lines of current of values ψ_{i+1} and ψ_{i+2}. The portion is determined by :

$$\Delta Q=|\psi_{i+2}-\psi_{i+1}|$$

Example

We consider, on Figure 5, a simulation domain where the contour is made of two solid boundaries and two open boundaries. The two solid boundaries are delineated by the curves AD and BC. The open boundaries are delineated by the curve AB in entrance and by the curve CD in exit. The discharge Q simulated in permanent regime, which transits in the domain is *a priori* unknown. To find it, simply calculate :

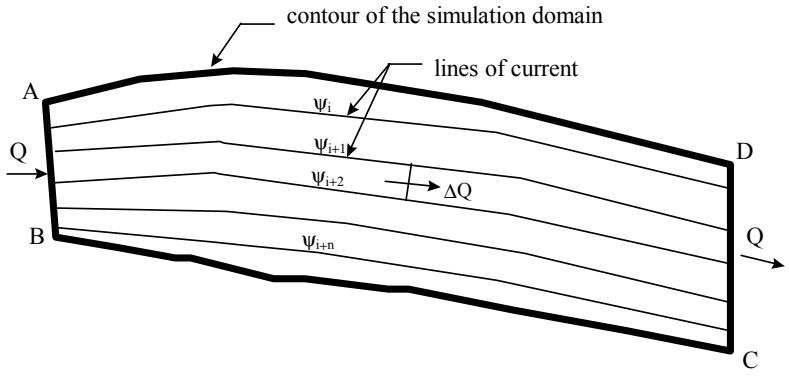
$$Q_{AB}=|\psi_A-\psi_B|$$

where ψ_A et ψ_B are the values of the function current at points A and B respectively. In the same manner, the outgoing discharge can be calculated by :

$$Q_{CD}=|\psi_C-\psi_D|$$

In theory, $Q_{AB}=Q_{CD}$.

Figure 5 : Graphic representation of the function current.



Chapter 5 Appendix

- Language dictionary
- Library of finite elements
- Library of temporal schemes
- Processing of transient data
- Block dependencies
- Example of command file
- Formats of input files
- Formats of results files

Language dictionary

The language dictionary of HYDROSIM proposes three work languages :

- HYDROSIM in English
- HYDROSIM in Spanish
- HYDROSIM in French

HYDROSIM in English

To use the English version (ENGlish), define the variable LANGUE at :

```
_LANGUE='.eng'
```

HYDROSIM in Spanish

To use the Spanish version (ESPagnol) define the variable LANGUE at :

```
_LANGUE='.esp'
```

HYDROSIM in French

To use the French version (FRanÇais), define the variable LANGUE at :

```
_LANGUE='.frc'
```

Library of finite elements

The library of finite elements of **{** XE "éléments finis" **}** HYDROSIM proposes two types of finite elements**{** XE "éléments finis" **}** :

- Finite element SVC
- Finite element SVCRNM

Finite element SVC

Named SVC by reference to the Saint-Venant**{** XE "Saint-Venant" **}** equations in Conservative form.

- How to reach it?
- Function
- Properties
- Boundary conditions
- Solicitations
- Initial solution

How to reach it?

To reach it, in the command file, the variable ELTYP must be defined as follows :

```
_ELTYP='SVC'
```

Function

SVC is a six node triangular finite element distributed according to the scheme one on each vertex and one in the middle of each edge. It is used to discretize the two-dimensional Saint-Venant**{** XE "Saint-Venant" **}** equations in the conservative form. It is dedicated to the study of hydrodynamics in rivers and estuaries. It supports the concept of Drying/Wetting of shores. It admits

three degrees of freedom per node, the scalar - water level, and the vector - specific discharge.

Properties

- Geometric
- Global
- Elementary
- Nodal

Geometric

Number of dimensions NDIM**{** XE "NDIM" **}**=2 ;

Number of nodes per element NNEL=6**.**

Global

Number of global properties to NPRGL=13 :

1 - gravity (9.75258282 m/s^2<=g<=9.6605398m/s^2)

2 - latitude

3 - constant turbulent viscosity

4 - mixing length coefficient**{** XE "longueur de mélange" **}**

5 - mesh-related mixing length coefficient

6 - lower bound of viscosity

7 - upper bound of viscosity

8 - penalization of Manning**{** XE "Manning" **}** coefficient for Drying (=10)

9 - porosity for Drying(=1)

10 - convection coefficient **{** XE "convection" **}** (=1)

11 - Peclet number **{** XE "Peclet" **}** (=0.5)

12 - free surface smoothing coefficient (=10^{-05})

13 - minimum depth admissible (=10^{-03}m)

Elementary

No elementary properties to read NPREL**{** XE "NPREL" **}**=0.

Nodal

Number of nodal properties to read NPRNL**{** XE "NPRNL" **}**=3 :

1 - terrain topography **{** XE "topographie du terrain" **}**

2 - Manning coefficient **{** XE "Manning" **}**

3 - ice thickness**{** XE "glace" **}**

Boundary conditions

The boundary conditions (B. C.) are applied on the degrees of freedom at the contour of the domain. The number of degrees of freedom per node is NDLN**{** XE "NDLN" **}**=3 : in the order, the following specific discharge in x (q_x), the following specific discharge in y (q_y) and the level of the free surface (h). The water level at the nodes middle of edge is systematically imposed internally (implicit B.C.). It is evaluated after the solution by giving it the mean value at the node vertex to the corresponding edge.

In a situation of flow simulation in a domain with complex geometry, the B.C. on the specific discharge **q**(q_x,q_y) must be expressed in the normal-tangent coordinate system. In this case, **q** admits q_n and q_t as components.

- Solid boundary
- Open boundary
- Convention

Solid boundary

On a solid boundary, a condition of impermeability q_n=0 is always imposed. We can leave q_t free or exploit a no flow condition q_t=q_n=0 in the case of a confined flow.

Remark**{** XE "Remarque" **}** : impermeability is the default condition.

Open boundary

On an open boundary, the water level is always imposed. If the flow direction is known, set q_t=0

Remark**{** XE "Remarque" **}** : on an entrance boundary, the discharge can be imposed in concentrated solicitation (see Solicitations) instead of the water level if the flow is sub-critical. In the case of critical or supra critical flow, h and q_n are imposed.

Convention

The code convention to introduce the B.C. is (see Boundary conditions file) :

1 - 1000000000 for q_x or 5000000000 for q_n

2 - 0100000000 for q_y or 0500000000 for q_t

3 - 0010000000 for h

Solicitations

- Concentrated
- Distributed

Concentrated

The concentrated solicitations introduce the discharge**{** XE "sollicitations :concentrées" **}** Q(m^3/s) at an open boundary of the simulation domain. The sign convention supposes positive (+) an entering discharge and negative (-) an outgoing discharge The concentrated solicitations are applied only on the vertex nodes.

In the concentrated solicitations file, they are associated with the third nodal degree of freedom. (see Solicitations file).

Distributed

The distributed solicitations introduce the wind speed components w_x and w_y, respectively following x and y, which act on the entire simulation domain, as well as the normal entering(sign +)/ outgoing (sign -) flux q_n by the open boundaries. HYDROSIM converts the wind speeds in equivalent distributed solicitations on the entire domain in accordance with the Wu discontinuous law, while the normal flux is converted in an equivalent distributed solicitation on the contour of the domain.

In the distributed solicitations file, the wind components x and y are associated respectively with the first and the second nodal degree of freedom. The normal flux is associated with the third degree of freedom (see Solicitations file).

Initial solution

Number of terms of initialization NTINI**{** XE "NTINI" **}**=7 :

1 - initial specific discharge q_x^0

2 - initial specific discharge q_y^0

3 - water level h^0 at point of reference

4 - slope S_x^0 of water body

5 - slope S_y^0 of water body

6 - coordinate x^0 of point of reference

7 - coordinate y^0 of point of reference

The variables of initialization allow to build on choice two types of initial solution :

a) hydrostatic solution : h^0=constant and all the other terms are set at 0.

b) quasi-linear hydrodynamic solution : consists in defining a water body answering the relation $h(x,y)=h^0+S_x^0(x-x^0)+S_y^0(y-y^0)$, and to set $q_x^0=q_y^0=0$. Internally, the code determines the resulting specific discharge **q**(x,y) by a Chézy**{** XE "Chézy" **}**-Manning law**{** XE "Manning" **}**.

Finite element SVCRNM

Named SVCRNM by reference to the Saint-Venant**{** XE "Saint-Venant" **}** equations in Conservative form ReNuMbered.

- How to reach it?
- Function
- Properties
- Boundary conditions
- Solicitations
- Initial solution

How to reach it?

To reach it, in the command file the variable ELTYP must be defined as follows :

```
_ ELTYP='SVCRNM'
```

Function

SVCRNM is a six node triangular finite element distributed according to the scheme one on each vertex and one in the middle of each edge. It is used to discretize the two-dimensional Saint-Venant**{** XE "Saint-Venant" **}** equations in the conservative form. It is dedicated to the study of hydrodynamics in rivers and estuaries. It supports the concept of Drying/Wetting of shores. It admits three degrees of freedom per node, the scalar - water level, and the vector - specific discharge.

SVCRNM is identical to Finite element SVC ; however it is more performing in the solution by the GMRES iterative method. On the other end, it is recommended to use Finite element SVC which consumes a lot less memory space than SVCRNM, when GMRES is coupled with a ILU preconditioning with a maximum fill level (ILU=-1).

Properties

- Geometric
- Global

- Elementary
- Nodal

Geometric

Number of NDIM{ XE "NDIM" }=2 ;

Number of nodes per element NNEL=6.

Global

Number of global properties to read NPRGL=13 :

1 - gravity (9.75258282 m/s^2<=g<=9.6605398m/s^2)

2 - latitude

3 - constant turbulent viscosity

4 - mixing length coefficient{ XE "longueur de mélange" }

5 - mesh-related mixing length coefficient

6 - lower bound of viscosity

7 - upper bound of viscosity

8 - penalization of Manning{ XE "Manning" } coefficient for Drying (=10)

9 - porosity for Drying(=1)

10 - convection coefficient { XE "convection" } (=1)

11 - Peclet number { XE "Peclet" } (=0.5)

12 - free surface smoothing coefficient (=10^{-05})

13 - minimum depth admissible (=10^{-03}m)

Elementary

No elementary properties to read NPREL{ XE "NPREL" }=0.

Nodal

Number of nodal properties to read NPRNL{ XE "NPRNL" }=3 :

1 - terrain topography { XE "topographie du terrain" }

2 - Manning coefficient { XE "Manning" }

3 - ice thickness { XE "glace" }

Boundary conditions

The boundary conditions (B. C.) are applied on the degrees of freedom at the contour of the domain. The number of degrees of

freedom per node is NDLN{ XE "NDLN" }=3 : in the order, the following specific discharge in x (q_x), the following specific discharge in y (q_y) and the level of the free surface (h). The water level at the nodes middle of edge is systematically imposed internally (implicit B.C.). It is evaluated after the solution by giving it the mean value at the node vertex to the corresponding edge.

In a situation of flow simulation in a domain with complex geometry, the B.C. on the specific discharge $\mathbf{q}(q_x,q_y)$ must be expressed in the normal-tangent coordinate system. In this case, **q** admits q_n and q_t as components.

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- Open boundary
- Convention

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On a solid boundary, a condition of impermeability $q_n=0$ is always imposed. We can leave q_t free or exploit a no flow condition $q_t=q_n=0$ in the case of a confined flow.

Remark{ XE "Remarque" } : impermeability is the default condition.

Open boundary

On an open boundary, the water level is always imposed. If the flow direction is known, set $q_t=0$

Remark{ XE "Remarque" } : on an entrance boundary, the discharge can be imposed in concentrated solicitation (see Solicitations) instead of the water level if the flow is sub-critical. In the case of critical or supra critical flow, h and q_n are imposed.

Convention

The code convention to introduce the B.C. is (see Boundary conditions file) :

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2 - 0100000000 for q_y or 0500000000 for q_t

3 - 0010000000 for h

Solicitations

- Concentrated
- Distributed

Concentrated

The concentrated solicitations introduce the discharge**{** XE "sollicitations :concentrées" **}** Q(m^3/s) at an open boundary of the simulation domain. The sign convention supposes positive (+) an entering discharge and negative (-) an outgoing discharge The concentrated solicitations are applied only on the vertex nodes.

In the concentrated solicitations file, they are associated with the third nodal degree of freedom. (see Solicitations file).

Distributed

The distributed solicitations introduce the wind speed components w_x and w_y, respectively following x and y, which act on the entire simulation domain, as well as the normal entering(sign +)/ outgoing (sign -) flux q_n by the open boundaries. HYDROSIM converts the wind speeds in equivalent distributed solicitations on the entire domain in accordance with the Wu discontinuous law, while the normal flux is converted in an equivalent distributed solicitation on the contour of the domain.

In the distributed solicitations file, the wind components x and y are associated respectively with the first and the second nodal degree of freedom. The normal flux is associated with the third degree of freedom (see Solicitations file).

Initial solution

Number of terms of initialization NTINI**{** XE "NTINI" **}**=7 :

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2 - initial specific discharge q_y^0

3 - water level h^0 at point of reference

4 - slope S_x^0 of water body

5 - slope S_y^0 of water body

6 - coordinate x^0 of point of reference

7 - coordinate y^0 of point of reference

The variables of initialization allow to build on choice two types of initial solution :

a) hydrostatic solution : h^0=constant and all the other terms are set at 0.

b) quasi-linear hydrodynamic solution : consists in defining a water body answering the relation $h(x,y)=h^0+S_x^0(x-x^0)+S_y^0(y-y^0)$, and to set $q_x^0=q_y^0=0$. Internally, the code determines the resulting specific discharge **q**(x,y) by a Chézy**{** XE "Chézy" **}**-Manning law**{** XE "Manning" **}**.

Library of temporal schemes

The library of temporal schemes of HYDROSIM proposes two methods to discretize time :

- EULER
- STATIQ

EULER

This a solution scheme depending on time of which the approximation is of the type EULER**{** XE "Euler" **}** (approximation of the first order). Its use is required to simulate non permanent or transient physical processes. To reach the EULER scheme, the syntax is :**{** XE "Euler" **}**

```
_STEMP='EULER'
```

STATIQ

This is a solution scheme independent of time, or static. Its use is required to simulate permanent physical processes. To reach the STATIQ scheme, the syntax is :

```
_STEMP='STATIQ'
```

Processing of transient data

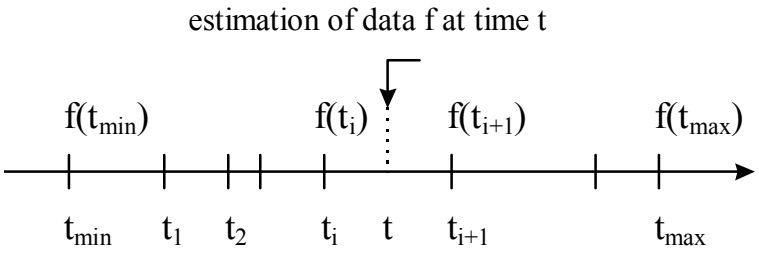
The data of an input file are said transient as soon as we have two or more sequences of values with which is systematically associated a time value (see Formats of input files). The software HYDROSIM has the capacity to process transient input data in the course of a simulation evolving with time. More precisely, it is possible to predict the input data at a given time through an interpolation procedure. The principle for the determination of the values of transient data, valid for any input data, is the following :

Figure 6 presents the variation range of a function f. The range is comprised between the times t_{min} and t_{max}. At the various times t_1, t_2, t_i,..., t_{i+1},... is associated a value of f. Thus, at time t, the value of f is equal to :

- if $t<t_{min}$, $f(t)=f(t_{min})$
- if $t_i<t<t_{i+1}$, $f(t)=at+b$ with $a=[f(t_{i+1})-f(t_i)]/(t_{i+1}-t_i)$ and $b=1/2[f(t_i)+f(t_{i+1})-a(t_i+t_{i+1})]$

- if $t>t_{max}$, $f(t)=f(t_{max})$

Figure 6 : Time variation range of a data f.



Remark{ XE "Remarque" } : The sequences of transient data must stored sequentially so as to have a monotonous time increase.

Block dependencies

Not only are the blocks dependent on each other, they also depend on the variables. Tables are used to identify the dependencies using the following notation convention :

1 - mandatory dependency : X ;

2 - optional dependency: O ;

The different types of dependencies are :

- Dependencies between blocks
- Dependencies blocks-variables

Dependencies between blocks

In Table 2 below, the blocks called are listed in columns 2 to 16 and the dependency blocks are listed in the first column. Only the block STOP is not listed since it depends of no other block, and vice versa.

Table 2 : Dependencies between blocks.

	COND	COOR	ELEM	ERR	FCRT	FIN	FORM	INIT	POST	PRCO	PREL	PRGL	PRNO	RESI	SOLC	SOLR	SOLV
COND														X	X	X	X
COOR	X		X	X	X			X	X	X	X		X	X	X	X	X
ELEM	X			X	X			X	X	X	X		X	X	X	X	X
FORM		X										X					

INIT	x			x	x	x			x					x	x	x	x
PRCO																	o
PREL	x			x	x			x	x					x	x	x	x
PRGL	x			x	x			x	x		x		x	x	x	x	x
PRNO	x			x	x			x	x					x	x	x	x
SOLC														o			o
SOLR														o			o

Dependencies blocks-variables

- Dependencies blocks-strings of characters
- Dependencies blocks-integer variables
- Dependencies of blocks-real variables

Dependencies blocks-strings of characters

In Table 3 below, the blocks called are listed in columns 2 to 15. The blocks PRCO, PRGL and STOP are not listed since they depend on no variables. The dependency variables of the type string of characters are listed in the first column.

Table 3 : Dependencies of the blocks to string of characters.

	COND	COOR	ELEM	ERR	FCRT	FIN	FORM	INIT	POST	PREL	PRNO	RESI	SOLC	SOLR	SOLV
ELTYP							X								
MCND	X														
MCOR		X													
MELE			X												
MERR				X											
MEXE															O
MFCR					X										
MFIL	O	O	O	O	O	O		O	O	O	O	O	O	O	O
MFIN						X									
MINI								O							
MPRE										O					
MPRN											O				
MPST									X						

MRES												X			
MSLC													O		
MSLR														O	
STEMP							X								

Dependencies blocks-integer variables

In Table 4 below, only two blocks depend on integer variables.

Table 4 : Dependencies of blocks to integer variables.

	FCRT	PRCO	SOLV
ILU	O	O	
IMPR			O
NITER	O		O
NPAS			O
NPREC			O
NRDEM	O		O

Dependencies of blocks-real variables

In Table 5, below, a total of ten blocks, listed in columns 2 to 11, depend on real variables, listed in the first column.

Table 5 : Dependencies of blocks to real variables.

	COND	FCRT	INIT	POST	PRCO	PREL	PRNO	RESI	SOLC	SOLR	SOLV
ALFA								O			O
DELPRT					O						
DPAS								O			O
EPSDL		O									O
OMEGA		O									O
TINI				O							O
TASCND	O										
TASINI			O								
TASPRE						O					
TASPRN							O				
TASSLC									O		
TASSLR										O	

Example of command file

- Stationary case
- Non-stationary or transient case

Stationary case

```
#-----------------------------------------------
---------------------------
#      EXAMPLE OF COMMAND FILE FOR HYDROSIM
#   Simulation directory : c :\hydrosim\simul\
#   Generic name of data and results files :
test
#   Stationary simulation
#   Minimum print detail level :M=0
#-----------------------------------------------
----------------------------
!--- DEFINITION OF THE FORMULATION
!--- TYPE OF ELEMENT
_ELTYP='SVCRNM'
!--- TEMPORAL SCHEME
_STEMP='STATIQ'
FORM[0]
!--- DEFINITION OF FILES
_MFIL=' c :\hydrosim\simul\test'
!--- SIMULTION PROGRESS FILE
MEXE='.dat'
!--- READING OF COORDINATES
_MCOR='.cor'
COOR[0]
!--- READING OF CONNECTIVITIES
_MELE='.ele'
ELEM[0]
!--- READING OF GLOBAL PROPERTIES
PRGL[0](9.8,0,1e-6,1.0,0.0,1e-
6,100,10.,1.0,1.0,0.5,1e-5,1e-3)
```

```
!--- READING OF NODAL PROPERTIES
_MPRN=’.prn’
PRNO[0]
!--- CALL OF BLOCK OF ELEMENTARY PROPERTIES
PREL[0]
!--- INITIALIZATION OF THE SOLUTION ON FILE
_MINI=’.deb’
INIT[0]
!--- READING OF BOUNDARY CONDITIONS
_MCND=’.cnd’
COND[0]
!--- READING OF CONCENTRATED SOLICITATIONS
_MSLC=’.slc’
SOLC[0]
!--- READING OF DISTRIBUTED SOLICITATIONS
_MSLR=’.slr’
SOLR[0]
!--- PRECONDITIONING
_ILU=0
_DELPRT=1.0E-08
PRCO[0]
!--- STATIONARY SOLUTION BY PAR GMRES
! NONLINEAR AND ILU PRECONDITIONING WITH
! 2 PRECONDITIONING, 10 RESTRATS,
! 25 ITERATIONS, PRECISION 10-6, LIMITORS OFDE
! SOLUTION ACTIVE : ΔU=ΔV=0.25m/s, Δh=0.1m
_IMPR=3
_NPREC=2
_NRDEM=10
_NITER=25
_EPSDL=1.0E-06
_OMEGA=1
SOLV[0](0.25,0.25,0.1)
!--- RESULTS : PRINTING OF FINAL FINALE
_MFIN=’.fin’
FIN[0]
!--- RESULTS : RESIDUALS
_MRES=’.res’
RESI[0]
```

```
!--- RESULTS : POST-PROCESSING
_MPST=’.pst’
POST[0]
!--- RESULTS : NUMERICAL ERRORS
_MERR=’.err’
ERR[0]
!--- RESULTS : FUNCTION CURRENT
_MFCR=’.fcr’
_ILU=-1
_NRDEM=1
_NITER=1
_OMEGA=1
_EPSDL=1.E-06
FCRT[0]
!--- STOP THE SIMULATION
STOP
```

Non-stationary or transient case

```
#-----------------------------------------------
---------------------------
#     EXAMPLE OF COMMAND FILE FOR HYDROSIM
# Simulation directory : c :\hydrosim\simul\
#   Generic name of data and results : test
#   Non-stationary simulation (boundary
conditions and
#    initial solution vary in time)
#   Minimum print detail level :M=0
#-----------------------------------------------
---------------------------
!--- DEFINITION OF THE FORMULATION
!--- TYPE OF ELEMENT
_ELTYP=’SVCRNM’
!--- TEMPORAL SHEME
_STEMP=’EULER’
FORM[0]
!--- DEFINITION OF FILES
_MFIL=’ c :\hydrosim\simul\test’
```

```
!--- SIMULATION PROGRESS FILE
MEXE='.dat'
!--- READING OF COORDINATES
_MCOR='.cor'
COOR[0]
!--- READING OF CONNECTIVITIES
_MELE='.ele'
ELEM[0]
!--- READING OF GLOBAL PROPERTIES
PRGL[0](9.8,0,1e-6,1.0,0.0,1e-
6,100,10.,1.0,1.0,0.5,1e-5,1e-3)
!--- READING OF NODAL PROPERTIES
_MPRN='.prn'
PRNO[0]
!--- CALL OF BLOCK OF ELEMENTARY PROPERTIES
PREL[0]
!--- INITIALIZATION OF THE SOLUTION ON FILE
_MINI='.deb'
_TASINI=0.
INIT[0]
!--- READING OF BOUNDARY CONDITIONS
_MCND='.cnd'
_TASCND=0.
COND[0]
!--- READING OF CONCENTRATED SOLICITATIONS
_MSLC='.slc'
SOLC[0]
!--- READING OF DISTRIBUTED SOLICITATIONS
_MSLR='.slr'
SOLR[0]
!--- PRECONDITIONING
_ILU=0
_DELPRT=1.0E-08
PRCO[0]
!--- NON-STATIONARY SOLUTION BY EULER-
! IMPLICIT AND GMRES NONLINEAR
! PRECONDITONING BY ILU WITH T10 TIME STEPS
! OF 60 SECONDS
! 2 PRECONDITIONING, 10 RESTARTS,
```

```
! 25 ITERATIONS, PRECISION 10-6, LIMITORS OF
! SOLUTION ACTIVE : ΔU=ΔV=0.25m/s, Δh=0.1m
_TINI=0.00
_DPAS=60.00
_ALFA=1.0
_IMPR=3
_NPAS=10
_NPREC=2
_NRDEM=10
_NITER=25
_EPSDL=1.0E-06
_OMEGA=1
SOLV[0](0.25,0.25,0.1)
!--- RESULTS : PRINTING OF FINAL SOLUTION
_MFIN='.fin'
FIN[0]
!--- RESULTS : RESIDUALS
_MRES='.res'
RESI[0]
!--- RESULTS : POST-PROCESSING
_MPST='.pst'
POST[0]
!--- RESULTS : NUMERICAL ERRORS
_MERR='.err'
ERR[0]
!--- RESULTS : FUNCTION CURRENT
_MFCR='.fcr'
_ILU=-1
_NRDEM=1
_NITER=1
_OMEGA=1
_EPSDL=1.E-06
FCRT[0]
!--- STOP THE SIMULATION
STOP
```

Formats of input files

This section presents the formats of the various files of the data necessary for{ XE "fichier:formats" } HYDROSIM to conduct a simulation.

There are two categories of data : static and time-variable. The dynamic data are introduced by sequences, each corresponding to a precise time which must be systematically defined first (see Processing of transient data). In all logic, a static data file includes a single sequence independent of time. For certain input files, a simple example is proposed. The input files read by HYDROSIM are :

- Boundary conditions file
- Connectivit
- Coordinates file
- Elementary properties file
- Nodal properties file
- Solicitations file
- Initial solution file
- Function current file

Boundary conditions file

The boundary conditions are a dynamic type data. The format is as follows :

Sequence	Lines	Format	Variables	Type
1	1	free	Tmp-cl	ASCII
	2 3 to m	10I1,3F24.0 13I6	for each group of nodes icod,(vcl(i),i=1,NDLN{ XE "NDLN" }) (kdimp(i),i=1,NBN)	
	m+1	I6	0 (end of sequence 1)	
2	1	free	Tmp-cl	
	2 3 to m	10I1,3F24.0 13I6	for each group of nodes icod,(vcl(i),i=1,NDLN{ XE "NDLN" }) (kdimp(i),i=1,NBN)	

	m+1	I6	0 (end of sequence 2)	
. . .	. . .	. . .	. . .	
n	1	free	Tmp-cl	
	2 3 to m	10I1,3F24.0 13I6	for each group of nodes icod,(vcl(i),i=1,NDLN{ XE "NDLN" }) (kdimp(i),i=1,NBN)	
	m+1	I6	0 (end of sequence n)	

Tmp-cl : Time associated with each sequence of boundary conditions.

NBN : Number of nodes sharing the same boundary conditions.

NDLN{ XE "NDLN" } : Number of degrees of freedom per node.

ICOD : integer indicating the CODe assigned to each degree of freedom.

vcl : table of the VaLues of boundary conditions at each degree of freedom.

kdimp : table of the numbers of the nodes with imposed degrees of freedom.

Example :

At the nodes 1, 92 and 3567, the values of boundary conditions are -12.351 and 116 associated with the dof 1 and 3 respectively. At the nodes 44 and 5225, the values imposed are 10.009 and 115 associated with dof 2 and 3 respectively. Which gives

```
0.0
1010000000-12.351          0.0             116.
      1    92  3567
0110000000 0.0             10.009          115.
    44  5255
0
```

Connectivities file

The connectivities of the mesh elements are of the type static data. The file format is as follows:

Lines	Format	Variables	Type

1	free	NELT{ XE "NELT" }, NNEL	ASCII
2 to NELT{ XE "NELT" }+1	free	Node1,Node2,..., NodeNNEL	

NELT{ XE "NELT" } : Total number of elements.

NNEL : Number of nodes per element..

Example :

We consider a mesh with two elements and 6 nodes per element Which gives

```
2    6
1    5    9    6    3    2
1    4    7    8    9    5
```

Coordinates file

The coordinates of the mesh nodes are a static type data. The file format is as follows :

Lines	Format	Variables	Type
1	free	NNT{ XE "NNT" }, NDIM{ XE "NDIM" }	ASCII
2 to NNT{ XE "NNT" }+1	free	coord. X,Y,Z	

NNT{ XE "NNT" } : Total number of nodes.

NDIM{ XE "NDIM" } : Number of dimensions.

Example :

We consider a mesh with 5 nodes and 2 dimensions. Which gives

```
5    2
0.000 0.000
0.000 1.000
0.000 2.000
1.000 0.000
1.000 1.000
```

Elementary properties file

The elementary properties are dynamic type data. The file format is as follows :

Sequence	Lines	Format	Variables	Type
1	1	free	NELT{ XE "NELT" },NPREL{ XE "NPREL" },Tmp-pre	ASCII
	2 to (NNT{ XE "NNT" }+1)	free	in,(vpre(i),i= 1,...,NPREL{ XE "NPREL" })	
2	1	free	NELT{ XE "NELT" },NPREL{ XE "NPREL" },Tmp-pre	
	2 to (NNT{ XE "NNT" }+1)	free	in,(vpre(i),i= 1,...,NPREL{ XE "NPREL" })	
. . .	. . .	. . .	. . .	
n	1	free	NELT{ XE "NELT" },NPREL{ XE "NPREL" },Tmp-pre	
	2 to (NNT{ XE "NNT" }+1)	free	in,(vpre(i),i= 1,...,NPREL{ XE "NPREL" })	

Tmp-pre : Time associated with each sequence of elementary properties.

NELT{ XE "NELT" } : Total number of elements.

NPREL{ XE "NPREL" } : Number of properties to read per element.

vpre : Table of the values of the elementary properties.

Nodal properties file

The nodal properties are dynamic type data. The file format is as follows :

Sequence	Lines	Format	Variables	Type
1	1	free	NNT{ XE "NNT" },NPRNL{ XE "NPRNL" },Tmp-prn	ASCII
	2 to (NNT{ XE "NNT" }+1)	free	in,(vprn(i),i=1, ,NPRNL{ XE "NPRNL" })	
2	1	free	NNT{ XE "NNT" }, NPRNL{ XE "NPRNL" },Tmp-prn	
	2 to (NNT{ XE "NNT" }+1)	free	in,(vprn(i),i=1, ,NPRNL{ XE "NPRNL" })	
. . .	. . .	. . .	. . .	
n	1	free	NNT{ XE "NNT" }, NPRNL{ XE "NPRNL" },Tmp-prn	
	2 to (NNT{ XE "NNT" }+1)	free	in,(vprn(i),i=1, ,NPRNL{ XE "NPRNL" })	

Tmp-prn : Time associated with each sequence of nodal properties..

NNT{ XE "NNT" } : Total number of nodes.

NPRNL{ XE "NPRNL" } : Number of properties to read per node.

vprn : Table of the values of the nodal properties.

Example :

We consider a mesh with 5 nodes and 3 nodal properties per node. The three nodal values are 115, 0.02 and 0 for each node. Which gives :

```
5   3   0.0
115.00   0.020    0.0
115.00   0.020    0.0
115.00   0.020   0.0
115.00   0.020   0.0
115.00   0.020   0.0
```

Solicitations file

The concentrated and distributed solicitations are dynamic type data. Although the concentrated and distributed solicitations are stored in two different files, the format is identical and is as follows :

Sequence	Lines	Format	Variables	Type
1	1	free	Tmp-sl	ASCII
	2 3 to m	10I1,3F24.0 13I6	for each group of nodes icod,(vsldl(i),i=1,...,NDLN{ XE "NDLN" }) (ksimp(i),i=1,...,NBN)	
	m+1	I6	0 (end of sequence 1)	
2	1	free	Tmp-sl	
	2 3 to m	10I1,3F24.0 13I6	for each group of nodes icod,(vsldl(i),i=1,...,NDLN{ XE "NDLN" }) (ksimp(i),i=1,...,NBN)	
	m+1	I6	0 (end of sequence 2)	
. . .	. . .	. . .	. . .	
n	1	free	Tmp-sl	
	2 3 to m	10I1,3F24.0 13I6	for each group of nodes icod,(vsldl(i),i=1,...,NDLN{ XE "NDLN" }) (ksimp(i),i=1,...,NBN)	
	m+1	I6	0 (end of sequence n)	

Tmp-sl : Time associated with each sequence of Solicitations.

NBN : Number of nodes sharing the same solicitations.

NDLN{ XE "NDLN" } : Number of degrees of freedom per node.

icod : Integer indicating the CODe assigned to each degree of freedom.

vsldl : Table of the values of the solicitations associated with each degree of freedom.

ksimp : Table dof the node numbers with imposed solicitation..

Example :

At the nodes 1, 92 et 3567 the values of the imposed solicitations are -12.351 and 116 associated with the dof 1 and 3 respectively. At the nodes 44 and 5225 the values imposed are 10.009 and 115 associated with dof 2 and 3 respectively. Which gives

```
0.0
1010000000-12.351          0.0             116.
      1    92  3567
0110000000 0.0             10.009          115.
    44  5255
0
```

Initial solution file

The initial solution is a dynamic type data. The file format is as follows.

Sequence	Lines	Format	Variables	Type
1	1	free or non formatted	NNT{ XE "NNT" },NDLN{ XE "NDLN" },Tmp-ini	ASCII (by default) or binary
	2 to NNT{ XE "NNT" }*NTTEMP+1{ XE "NTTEMP" }	free or non formatted	(vddl(i),i=1,..,NDLN{ XE "NDLN" })	
2	1	free or non formatted	NNT{ XE "NNT" },NDLN{ XE "NDLN" },Tmp-ini	
	2 to NNT{ XE "NNT" }*NTTEMP+1{ XE "NTTEMP" }	free or non formatted	(vddl(i),i=1,..,NDLN{ XE "NDLN" })	
. . .	. . .	. . .	. . .	
	1	free	NNT{ XE "NNT" },NDLN{ XE "NDLN"	

		or non formatted	}, Tmp-ini	
n	2 to NNT{ XE "NNT" }*NTTEMP+1{ XE "NTTEMP" }	free or non formatted	(vddl(i),i=1,..,NDLN{ XE "NDLN" })	

Tmp-ini : Time associated with each sequence of the initial solution.

NNT{ XE "NNT" } : Total number of nodes.

NDLN{ XE "NDLN" } : Number of degrees of freedom per node.

NTTEMP{ XE "NTTEMP" } : Number of temporal terms (=1 for STEMP='STATIQ',=2 for STEMP='EULER').

vddl : Table of values of each degree of freedom.

Example :

We consider a mesh with 5 nodes and 3 degrees of freedom per node. The three values of the degrees of freedom are 0.0, 0.0 and 116.30 for each node. Which gives :

```
5   3   0.0
0.0   0.0    116.30
0.0   0.0    116.30
0.0   0.0   116.30
0.0   0.0   116.30
0.0   0.0   116.30
```

Formats of results files

This section presents the formats of the various files of the results generated by HYDROSIM following a simulation.

There are two categories of results : static and time variable. The dynamic results are generated in sequences, each corresponding to a precise time which is systematically defined first. In all logic, a static results file comprises a single sequence independent of time. The results files generated by HYDROSIM are :

- Degrees of freedom file
- Numerical errors file
- Post-processing file
- Residuals file
- Function current file

Degrees of freedom file

The degrees of freedom are a dynamic type data. The file format is as follows :

Sequence	Lines	Format	Variables	Type
1	1	free or non formatted	NNT{ XE "NNT" },NDLN{ XE "NDLN" },Tmp-fin	ASCII (by default) or binary
	2 to NNT{ XE "NNT" }*NTTEMP+1{ XE "NTTEMP" }	13(1X,1PE24.17) or non formatted	(vddl(i),i=1,..,NDLN{ XE "NDLN" })	
2	1	free or non formatted	NNT{ XE "NNT" },NDLN{ XE "NDLN" },Tmp-fin	
	2 to NNT{ XE "NNT" }*NTTEMP+1{ XE "NTTEMP" }	13(1X,1PE24.17) or non formatted	(vddl(i),i=1,..,NDLN{ XE "NDLN" })	
. .	. .	.. .	.. .	
n	1	non formatted	NNT{ XE "NNT" },NDLN{ XE "NDLN" },Tmp-fin	
	to NNT{ XE "NNT" }*NTTEMP+1{ XE "NTTEMP" }	13(1X,1PE24.17) or non formatted	(vddl(i),i=1,..,NDLN{ XE "NDLN" })	

Tmp-fin : Time associated with each sequence of the final solution..

NNT{ XE "NNT" } : Total number of nodes.

NDLN{ XE "NDLN" } : Number of degrees of freedom per node.

NTTEMP{ XE "NTTEMP" } : Number of temporal terms (=1 for STEMP='STATIQ',=2 for STEMP='EULER').

vddl : Table of the values of each degree of freedom.

Numerical errors file

The numerical errors ere a dynamic type data. The file format is as follows :

Sequence	Lines	Format	Variables	Type
1	1	free	NNT{ XE "NNT" },NDLN{ XE "NDLN" },Tmp-err	ASCII
	2 to (NNT{ XE "NNT" }+1)	13(1X,1PE24.17)	(verdl(i),i= 1,...,NDLN{ XE "NDLN" })	
2	1	free	NNT{ XE "NNT" },NDLN{ XE "NDLN" },Tmp-err	
	2 to (NNT{ XE "NNT" }+1)	13(1X,1PE24.17)	(verdl(i),i= 1,...,NDLN{ XE "NDLN" })	
.	.	.	.	
.	.	.	.	
.	.	.	.	
n	1	free	NNT{ XE "NNT" },NDLN{ XE "NDLN" },Tmp-err	
	2 to (NNT{ XE "NNT" }+1)	13(1X,1PE24.17)	(verdl(i),i= 1,...,NDLN{ XE "NDLN" })	

Tmp-err : Time associated with each sequence of numerical errors.

NNT{ XE "NNT" } : Total number of nodes.

NDLN{ XE "NDLN" } : Number of degrees of freedom per node.

verdl : Table of the values of the error on the degrees of freedom.

Post-processing file

Post-processing is a dynamic type data. The file format is as follows :

Sequence	Lines	Format	Variables	Type
1	1	free	NNT{ XE "NNT" },NPOST,Tmp-pst	ASCII
	2 to (NNT{ XE "NNT" }+1)	13(1X,1PE24.17)	(vpst(i),i= 1,...,NPOST)	
2	1	free	NNT{ XE "NNT" },NPOST,Tmp-pst	
	2 to (NNT{ XE "NNT" }+1)	13(1X,1PE24.17)	(vpst(i),i= 1,...,NPOST)	
. . .	. . .	. . .	. . .	
n	1	free	NNT{ XE "NNT" },NPOST,Tmp-pst	
	2 to (NNT{ XE "NNT" }+1)	13(1X,1PE24.17)	(vpst(i),i= 1,...,NPOST)	

Tmp-pst : Time associated with each sequence of PoST-processing.

NNT{ XE "NNT" } : Total number of nodes.

NPOST : Number of POST-processing values.

vpst : Table of the values of the PoST-processing.

Residuals file

The residuals are a dynamic type data. The file format is as follows :

Sequence	Lines	Format	Variables	Type
1	1	free	NNT{ XE "NNT" },NDLN{ XE "NDLN" },Tmp-res	
	2 to (NNT{ XE "NNT" }+1)	13(1X,1PE24.17)	(vredl(i),i= 1,...,NDLN{ XE "NDLN" })	

2	1	free	NNT{ XE "NNT" },NDLN{ XE "NDLN" },Tmp-res	ASCII
	2 to (NNT{ XE "NNT" }+1)	13(1X,1PE24.17)	(vredl(i),i= 1,...,NDLN{ XE "NDLN" })	
. . .	. . .	. . .	. . .	
n	1	free	NNT{ XE "NNT" },NDLN{ XE "NDLN" },Tmp-res	
	2 to (NNT{ XE "NNT" }+1)	13(1X,1PE24.17)	(vredl(i),i= 1,...,NDLN{ XE "NDLN" })	

Tmp-res : Time associated with each sequence of RESiduals.

NNT{ XE "NNT" } : Total number of nodes.

NDLN{ XE "NDLN" } : Number of degrees of freedom per node.

vredl : Table of the values of the residuals associated with the degrees of freedom.

Function current file

The function current is a static type data. The file format is as follows :

Sequence	Lignes	Format	Variables	Type
1	1	free	NNT{ XE "NNT" }	ASCII
	2 to (NNT{ XE "NNT" }+1)	free	vfcrt	

NNT{ XE "NNT" } : Total number of nodes.

vfcrt : Nodal value of the Function CuRrenT.

Chapter 6 Glossary

Approximation by finite elements
Method of calculation by sub-domains to approach the values of a function.

Band width
Positive integer obtained from the difference between the maximum and minimum connectivities.

Bottom level
Elevation z_f of the stream bottom in relation with a reference.

Boundary conditions
Conditions which must be satisfied by the degrees of freedom on the boundary of the simulation domain.

Chézy coefficient
Strictly positive real noted C, which translates the resistance of structures (river bed, ice and macrophytes) to the flow. Its value is generally between 30 for a strongly resistant structure and 60 for a smooth structure.

Connectivities
List of the geometric node numbers associated with each finite element of the mesh.

Continuous system
A system is continuous if it has an infinite number of degrees of freedom.

Convection
See convective acceleration.

Convective acceleration
In Eulerian representation, the convective acceleration is independent of time. It translates the spatial unevenness of the flow. It is at the origin of the formation of complex structures in the flow such as whirls or eddies.

Convergence of a non linear problem
A non linear solver calculates, from given initial conditions, by successive steps the solution to the problem. The solution is built by steps, an increment or a correction being applied at each step to update the solution. The calculation process reaches convergence when the solution stops evolving ; in other words, when the increment is so small as to have no more influence.

Degree of freedom
Parameter defining the state of a physical system.

Depth
Known as H, it is the result of the difference between the level of the free surface h and the level of the bottom z_f.

Direct solution method

The solution procedure of the equation system is conducted in a single step.

Discrete system

A system is discrete if it has a finite number of degrees of freedom. In a matrix form, it reads as follows : [K]{U}={F} where [K] is the rigidity matrix characterizing the system, {F} is the vector of the known solicitations, and {U} is the vector unknown solution.

Discretization

Operation ensuring the transformation of a temporal or spatial system into a discrete temporal or spatial system.

Drying/Wetting

Expression describing the capacity of the hydrodynamic model to predict the zones covered and uncovered by water. In HYDROSIM, the water level can freely dive underground. Thus, the depth values can be positive or negative. The sign convention adopted admits a zone covered as positive depth, and a zone uncovered as negative depth. The line of demarcation between the two zones is the shoreline.

Elementary properties

All the parameters related to an element

Euler scheme

First order discretization method of the derivative of a function f in relation with time t. Formally, the problem reads as follows : $\partial f/\partial t \approx (f^{t+\Delta t}-f^{t})/\Delta t$, where Δt is the time increment.

Finite element

Full geometric entity at one, two or three dimensions, made of a finite number of nodes placed inside or on the contour of the domain.

Froude Number

Adimensional number equal to the ratio of inertia and gravity forces. It is commonly used in hydraulics of open channel flows to define the flow regime. There are three categories of flow regime defined by the Froude Number : sub-critical if lower than one (<1), critical if equal to one (=1) and rapid flow or supra-critical if greater than one (>1). Its expression is $Fr=V/(gH)^{1/2}$ where V is the average velocity, g is the gravitational acceleration and H is the depth.

Global properties

All the parameters related to the mesh.

Hydrodynamic

Condition of equilibrium of moving water.

Hydrostatic

Condition of equilibrium of stagnant water.

ILU matrix

Preconditioning matrix obtained by the incomplete factorization of the finite element matrix of the equation system.

Initial conditions

To solve a non linear and/or time dependent problem, the initial state of the system must necessarily be defined. In practice, we select an initial solution which satisfies totally or in part the system of equations.

Iterative solution method

The solution procedure of the equation system is conducted in several successive steps called iterations.

Linear system

The matrix of the equation system is independent of the solution.

Local convergence

Local convergence or false convergence occurs when GMRES has converged while the norm of residuals remains high.

Manning coefficient

Strictly positive real noted n, which translates the resistance of structures (river bed, ice and macrophytes) to the flow. Its value is generally between 0.02 for a smooth structure and 0.05 for a strongly resistant structure.

Mathematical model

Series of equations, constituent laws, and conditions reproducing the behaviour of a given physical process.

Mesh

Homogeneous assembly of identical or complementary finite elements to discretize the domain of calculation.

Mesh skin

Finite element mesh forming the boundary of the mesh of the calculation domain.

NDIM

Number of DIMensions.

NDLN

Number of degrees of freedom per node.

NDLT

Total number of degrees of freedom.

NELT

Total number of elements.

NNEL

Number of nodes per element.

NNT

Total number of nodes.

Nodal properties

All the parameters related to the nodes

Non linear system

As opposed to a linear system, the matrix depends on the solution.

Normal-tangent coordinate system

Local orthonormed coordinate system used at the boundary of the simulation domain. Its components are the normal outgoing direction, in relation to the calculation domain, and the tangential direction at the boundary. In general, we use the notion of normal-tangent coordinate system to introduce the boundary conditions

NPRNL

Number of nodal properties to read.

NTINI

Number of initialization terms.

NTTEMP

Number of temporal terms

Numerical viscosity

Positive real noted ν_n having the dimensions of a kinematic viscosity. It assists the solver when the flow is strongly influenced by the convective acceleration, Its value is driven by the Peclet number which is usually set at 0.5.

Open boundary

Permeable boundary with non nil normal flow.

Peclet Number

Adimensional number also called local Reynolds number. Its expression is $Pe=VD/\nu$ where V is the average velocity, D is a characteristic dimension of the finite element and ν is the kinematic viscosity of the flow.

Preconditioning

Algebraic operation to transform, using a preconditioning matrix, the initial equation system in an equivalent equation system better adapted for the solution procedure by an iterative method.

Preconditioning matrix

Specific matrix exploited only when using an iterative method to execute the solution.

Relaxation

Strictly positive scalar which weights the increment of the solution to ensure the stability of the convergence of a non linear problem. If the scalar exceeds 1, it is known as over-relaxation ; below 1, it is known as under-relaxation. In general, it is lower than 1 for situations where convergence is difficult.

Residual

The residual measures to what extent does a solution satisfy the mathematical model. The residual is nil if a solution satisfies exactly the mathematical model. In the context of finite elements, the notion of residual is very important. It is a vector of which each component is associated with each degree of freedom. The validation operation of a solution consists, among other things, in making sure that it minimizes each component of the residual. In practice, the

control of the discrete norm L2 of the residual should be sufficient to release us from verifying each component one by one.

Rigidity matrix

Matrix resulting from the discretization by finite elements of the mathematical model.

Saint-Venant equations

Equations translating the principles of mass conservation and flow dynamics in rivers and estuaries. They are the result of the vertical integration of the tri-dimensional equations of Navier-Stokes in the presence of a free surface. Among the hypotheses, the horizontal dimensions are greatly superior to depth (theory of shallow waters), a hydrostatic distribution of the pressure, and a constant profile of the velocity on the vertical axis.

Shoreline

Line presenting a zero value depth.

Skyline

Storing method with variable band width for finite element matrix. The memory cost of skyline storing is related directly to the band width, in other words to the numbering of the mesh. The cost is minimum if the numbering of the mesh is optimized.

Solid boundary

Impermeable boundary with nil normal flow. Without adherence, the velocities are tangent to a solid boundary.

Solution

In the context of finite elements, it is an algebraic operation to determine the solution which satisfies the equation system related to the discretization of the mathematical model. It can be executed by two methods : a direct method, or an iterative method

Solution driver

Procedure assisting the solver by progressively varying one or several parameters

Solver

Algorithm which calculates the solution of the linear or non linear equation system.

Specific discharge

The discharge volume by unit of width.

Stokes problem

Expression used to indicate that the convective acceleration is neglected in the equations of fluid movement

Tangent matrix

Matrix resulting of the vector residual versus the vector solution.

Turbulent viscosity

Positive real noted ν_t having the dimensions of a kinematic viscosity. It quantifies the intensity of the turbulence of the flow.

Viscosity bounds

Lower and upper bounds of viscosity are introduced to control the calculation of turbulent and numerical viscosity during the solution, to avoid a default or an excessive dissipation in the system. In either one o the two situations, the solution convergence process may be seriously compromised. The values given to the bounds are determined by trial and error. They depend as much on the mesh as on the flow conditions.

Water level

Elevation h of the water body surface in relation with a reference.